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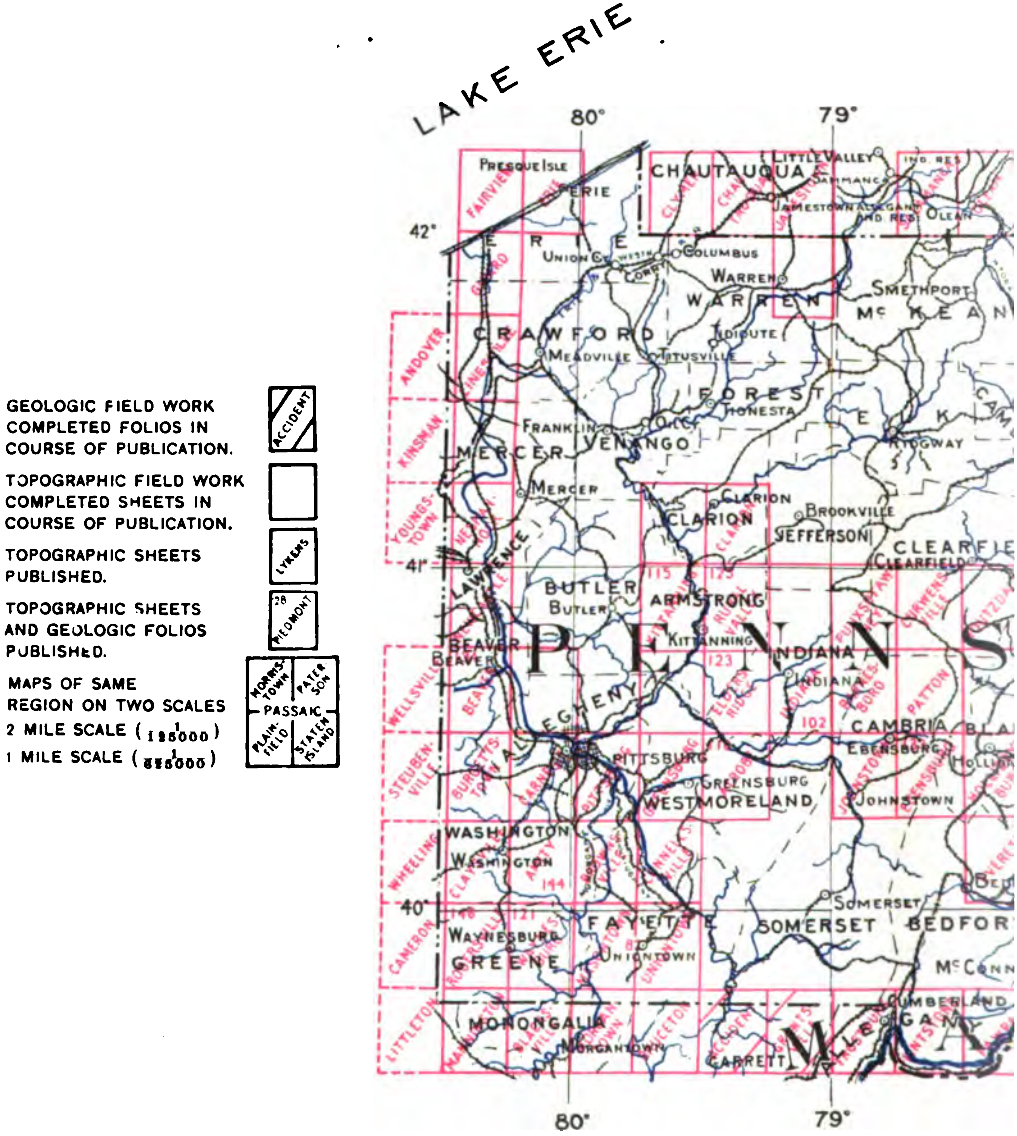

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PLATE A.

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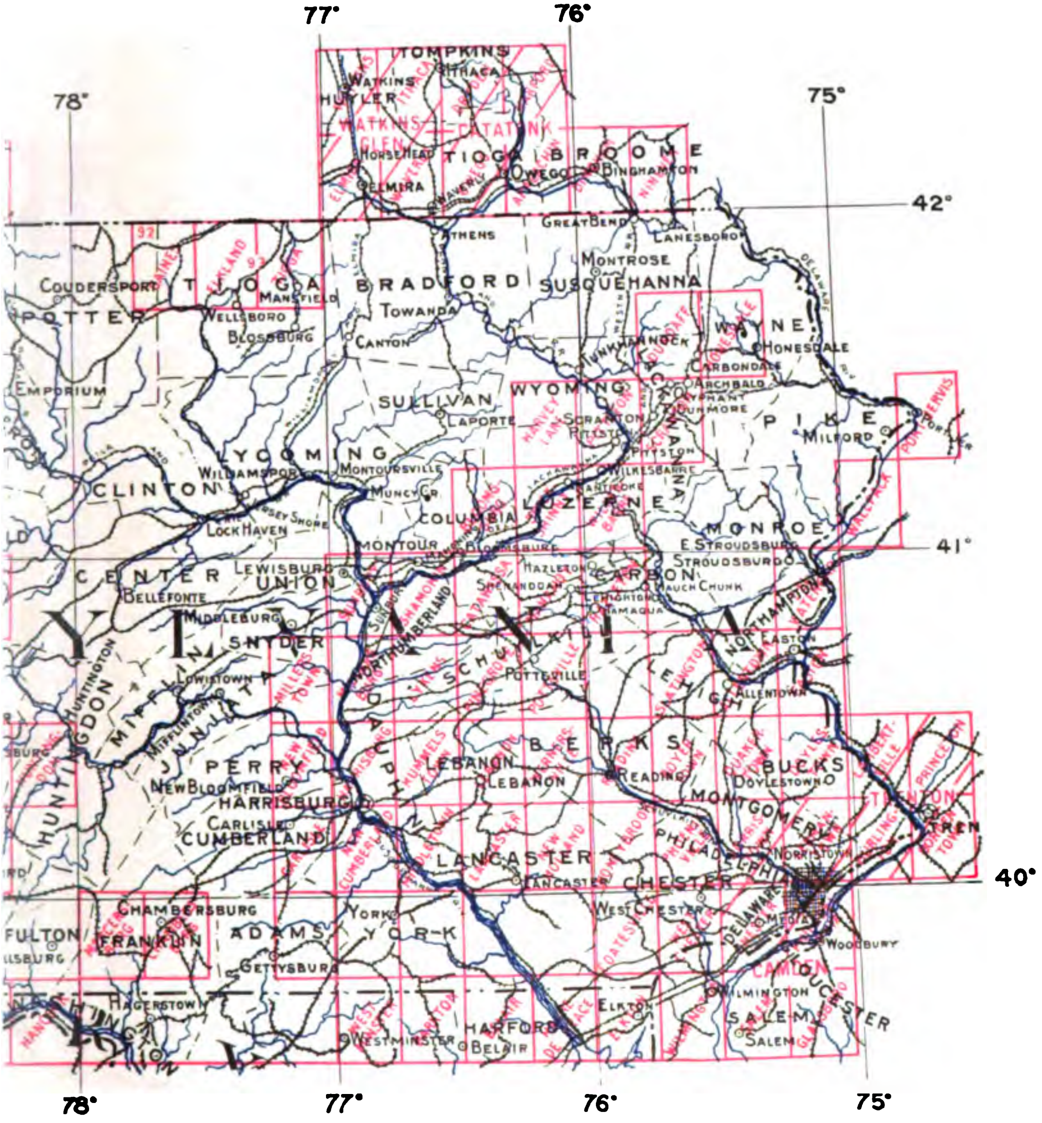

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AND

GEOLOGICAL SURVEY

OF

PENNSYLVANIA.

1906-1908.

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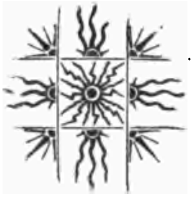

LETTER OF TRANSMITTAL.

To His Excellency Edwin S. Stuart, Governor of Pennsylvania:

Sir: The undersigned, Commissioners of the Topographic and Geologic Survey of Pennsylvania, have the honor to submit the following report of the work accomplished during the years 1906-07 and 1907-08.

Very respectfully,

GEORGE W. McNEES,
ANDREW S. McCREATH,
RICHARD R. HICE.

Harrisburg, Pa., July 1, 1908.

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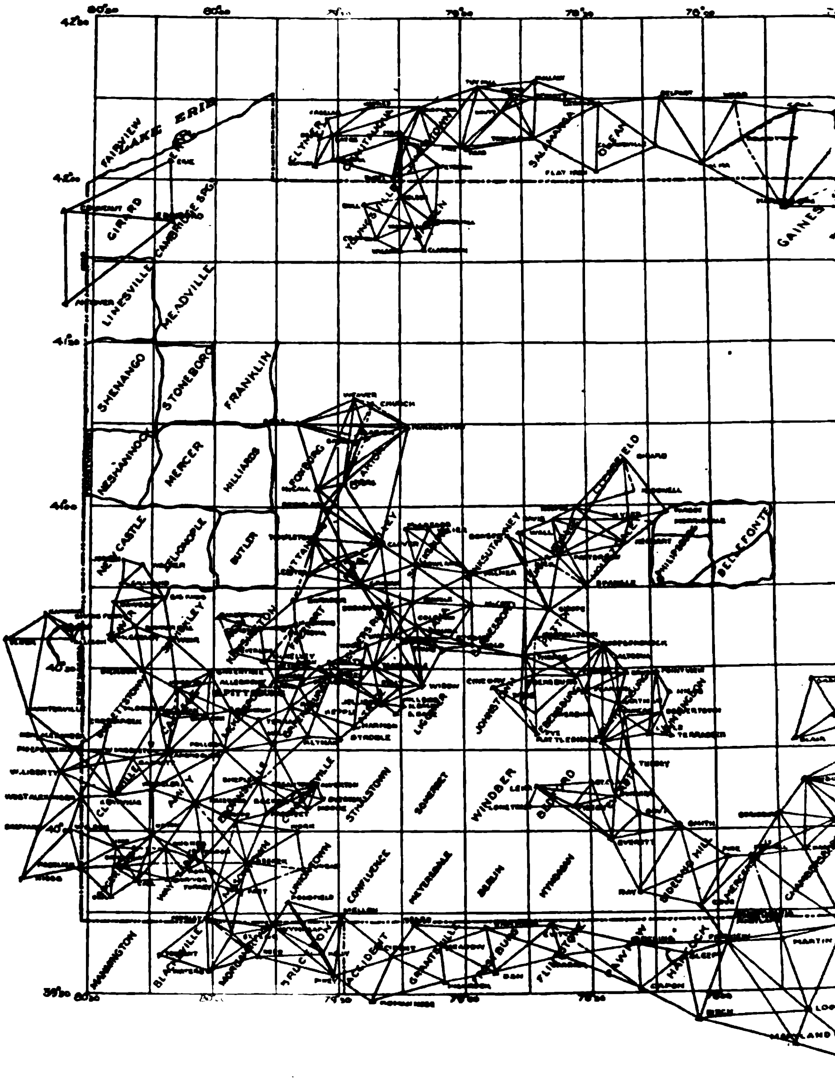

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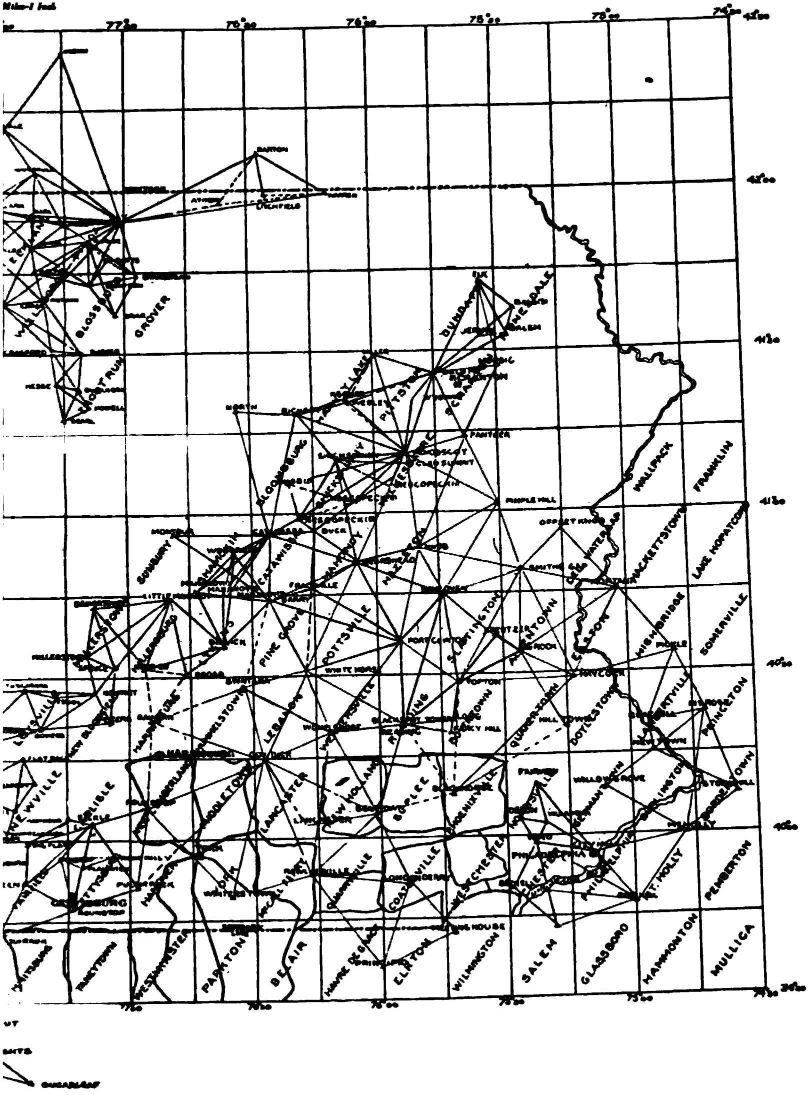

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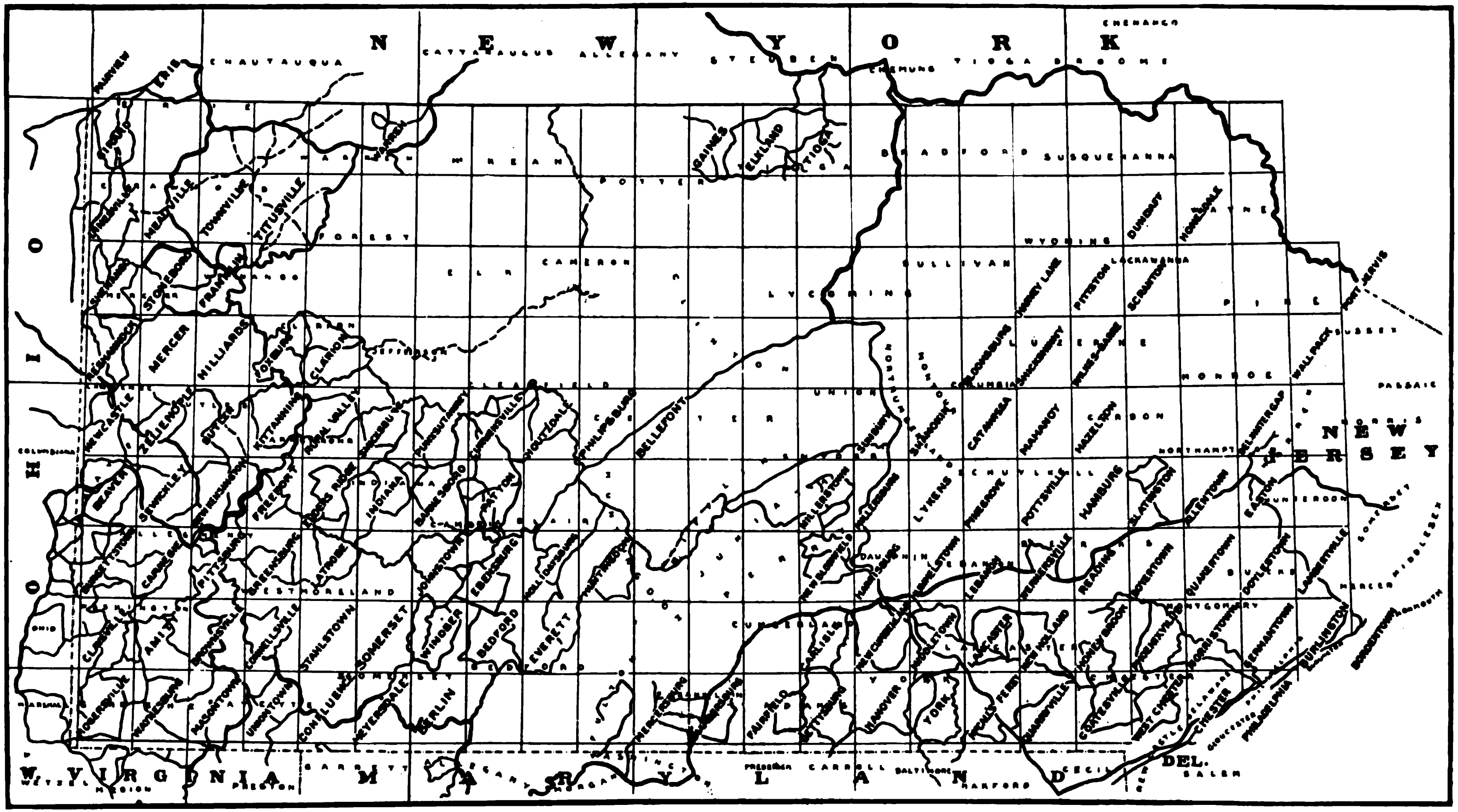
PLATE C.



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TOPOGRAPHIC AND GEOLOGICAL SURVEY OF PENNSYLVANIA.

INTRODUCTORY.

The work done under the direction of this Commission was originally started under the provisions of an Act of Assembly approved April 28, 1899 (See Appendix A.) Under the provisions of that act the Commission then appointed entered into a contract with the United States Geological Survey for the preparation of a topographic map of Pennsylvania, on the scale of 1:62,500, with contours for each 20 feet of elevation, and included in this contract were arrangements for geological work on a co-operative basis.

Results of the work done under the above mentioned agreement (and supplemental agreements continuing the same in force), will be found in two reports, one covering the work for the period ending June 30, 1901, and the second covering the work to June 1, 1906.

In addition to these reports some of the results of the geological work have appeared in publications of the United States Geological Survey and the completed maps have been issued by that organization. No provision whatever has been made for the compilation and publication of any of the results of the work by, or on behalf of, the State.

The results of the work thus far completed will be seen graphically represented on the Index Map, forming the frontispiece of this report, where is shown the condition of the work in the several portions of the State. The location of the various triangulation stations, and the generalized primary traverse lines are shown on plate B, and the relative positions of the several stations to one another are thus readily seen. Plate C shows the lines of the precise level net of the State, the elevations of which form the basis of the vertical control for the map.

The methods of location of triangulation stations, of the primary traverse and of the level lines were briefly described in the last report. There have been no changes in methods since that time, aside from the general increase in accuracy constantly demanded by the topographic branch of the United States Geological Survey.

Pennsylvania has an estimated area of 45,215 square miles, and for the purposes of the topographic map it is divided into "quadrangles" of 15 minutes on each side. Owing to the location of the State lines they do not coincide with the lines of these quadrangles, and there will be a number of quadrangles in the finished map which will embrace a portion of an adjoining State.

The total number of quadrangles lying wholly within the State, and those partly in other States will be about 240, and the completed map of the State will be composed of that number of sheets.

TOPOGRAPHIC WORK.

During the past two years primary control has been extended over 10 quadrangles. By triangulation, Smicksburg, Bedford, Fairfield, Gettysburg and Newville; embracing portions of four counties, as follows: Adams, Cumberland, Bedford and Jefferson.

By primary traverse control has also been extended over 5 quadrangles, McCall's Ferry, Quarryville, Bellefonte, Phillipsburg and Snowshoe; embracing portions of four counties, as follows: Chester, York, Centre and Clearfield.

During the same time vertical control has been extended over 12 quadrangles; Gettysburg, Middletown, Taneytown, Hanover, York, Bedford, Windber, Brookville, Smicksburg, Foxburg, Butler and Zelienople; embracing portions of 13 counties, as follows: Adams, Dauphin, Lebanon, Lancaster, York, Indiana, Bedford, Somerset, Clarion, Jefferson, Butler, Beaver and Lawrence.

The detailed results of the primary control, both horizontal and vertical, will be found in the appendices to this report.

The primary control has been extended each year from the beginning of the survey, until it now embraces, more or less, completely, 171 of the quadrangles included, or partly included, within the boundaries of the State, and the vertical control has been extended until it reaches 175 quadrangles, more or less completely.

Of the completed work maps have been printed and issued by the United States Geological Survey of 112 quadrangles, a full list of which will be found in Appendix D.

The work of the horizontal control must in all cases be kept in advance of the detailed mapping. Some portions of Pennsylvania are difficult to map and some portions are very difficult to control.

The broad, flat tops of our mountains are wooded and it is there almost impossible to get along lines of uninterrupted sight. For this reason it is necessary to erect high observing towers and to do this work economically it is necessary that quite an area be controlled at one time.

During the past years such an area has been found in the southern portion of the State, in the region of Somerset, an area embracing some nine quadrangles. During the past season it was attempted to get control of this region from the triangulation stations located in the adjoining quadrangles, but this was found impracticable. During the present season, therefore, all of this section yet uncontrolled will be triangulated from the south, using stations in Maryland of the trans-Continental net of the Coast Survey for the base. This means a relatively larger outlay for primary control than in the past two years, but if the amount of topographic work in the future is increased, we will need more primary control in advance of the detailed topographic work.

GEOLOGICAL WORK.

Good progress has been made in the geological work and most of the unfinished surveys have been completed in the field, and it is expected the close of the next field season will see all the uncompleted field work closed, with the exception of one quadrangle.

The results of the geological work are only published by the United States Geological Survey, and the issuing of reports is quite slow. In order that some of the results may be available an outline of geological explorations in the State and a summary of the results of the present co-operative work, including short accounts of the more important unpublished results have been incorporated in a short report and the same is submitted herewith as a part of this report (Appendix E).

In various publications of the United States Geological Survey 17 quadrangles of the State have been reported upon in the "folio" form of publication, and 4 "bulletins" have been issued covering the economic geology of 5 quadrangles.

Fourteen other short papers have been published in various bulletins, treating of special economic features. A list of all official publications will be found in the geological report (Appendix E).

RECOMMENDATIONS.

Since the submission of the last report of this Commission the work has been continuous and the results accomplished have been as great as could be expected from the outlay.

The demand, however, for all kinds of work is increasing, and it has been impossible for the Commission to comply with but a portion of the requests received. Two rules have been observed in the past in arranging the work, (1) to have the work done where the greatest industrial developments were in progress, and (2) supplementary to the first rule, in such sections to so place the work as to secure the greatest results for the money expended.

In applying the second of these rules many places have been passed by, where, if more money had been available, work would have been started before this time.

The topographic map is the basis for all study of the natural resources of any region. All classes of our citizens are interested in them. For the farmer they form the base on which the soil maps are made, and requests for maps for this purpose come from divers portions of the State. In the study of the water resources of a region they are indispensable, as such maps are the only accurate knowledge we can have of the area of water sheds and the relation of the component parts thereof; of the character of such water sheds, the fall of the streams and the slope of the catchment areas; the relation of forest areas and the proportion such areas bear to the whole of the basin and the several parts thereof; the value for water power purposes, and the location of plants that will most economically develop the maximum horse power of the stream; and, when coupled with a geological study of the sources of the water supply, and the relation of the supply to the several geological horizons, the value of such maps in connection with water supply for sanitary purposes is greater than all other uses. The value of such detailed maps for military purposes is evident. The relation of public highways to the surface relief; the character, size and position of railroad cuts and embankments; the relation of the forested areas to the relief and to one another, and all the natural features delineated on them, render them the most valuable map possible for military uses. The advantage of maps showing at once the relief, drainage basins, public highways, and the wooded areas cannot but be of great help in forestry.

To the people of Pennsylvania, however, nothing appeals to such an extent as the value of such maps in the development, and, too frequently the waste, of our mineral wealth. The engineer finds on them the information he needs, whether it be in the location of a line of railroad, or of a public highway; whether in the erection of a power plant, a coal mining plant and coke ovens, or of a manufacturing establishment; and this is information he could not secure in any other way and which means many thousands of dollars yearly to the people of Pennsylvania.

The demand for completed maps still continues and increases, and as said before requests for work continue to come in far greater numbers than can be reached by the limited funds at our command.

Geological work has also progressed under the co-operative plan. For a number of years there has been, for various reasons, some geological work remaining incomplete and during the last two years it has been the endeavor to get such work so carried along as to be in shape for publication. Most of this old work has been brought up to date and the close of the next field season will see practically all of the unfinished work ready for the writing of reports, which we hope will be ready for publication by the close of the year 1908-09.

The results of the co-operative geological work are only published by the United States Geological Survey and in the forms prescribed by that organization, all being presented to the world as the work of the National Survey. In this State publications are in two forms, "bulletins and "folios." The bulletins are almost entirely of an economic nature, treating of one or two quadrangles, without any attention to municipal lines or natural boundaries. The other form of publication, the "folio," presents the geology on maps made from the topographic base, with a few pages of explanatory text.

This publication is made to correspond with the form, and is a part of the general geological map of the United States, and as such necessarily conforms to certain general rules. That such a form of publication is valuable and easily followed by the geologist, the engineer, and those with some training in such studies must be admitted by all, but these publications are not popular with the general public. There has been a demand, and it is growing, for other work and other forms of publication, much in the line of such work in other states.

Never before has there been such a demand for accurate knowledge of our natural resources as at the present time. Pennsylvania stands too high as a mineral producer, and the contribution of her minerals to the wealth of the State are too large, to permit us to remain as we are. We stand at the head of the long line of manufacturing centers of the world, but if we are so to remain we must have accurate knowledge of our resources. Few of us, for example, realize the vast coal resources of Pennsylvania. Mining in 1907 of bituminous coal alone, 150,000,000 tons, three-fourths of which, probably, came from the "Pittsburg" vein alone, we are unable to fully comprehend such figures. But when we realize that over one-third of the coal is irretrievably lost in mining, and when with our topographic maps we can, with the aid of the geologist, estimate the remaining acreage of coal unmined, and the value of the several beds, and thus find that, even without increasing the rate of production, the possible limit of our supply, under existing conditions, is from 100 (White) to 250 (Campbell) years, we have figures that we all can comprehend.

Again, Pennsylvania is the second State in the Union in the value of her clay products, and ranks first as a producer of refractories. But can we hold this position? Other sections are making vast progress in the production of refractories, and it is only by the systematic study of our various clay horizons and investigation of the technology of clay working and the relation of the products made from the several clays, by the various methods of manufacture, to the numerous uses to which they are applied, that we can even approximately hold our present position. Many other examples might be cited in which geological work is equally needed.

The solutions of such questions are the purposes of a State Geological Survey. The necessity of such work needs no argument. Over 20 states east of the Mississippi river now have vigorous surveys organized, but Pennsylvania, standing at the top as a mineral State and with corresponding demands for systematic study of her resources, is calmly letting others forge ahead and secure positions that they will retain.

At the Conference of Governors at the White House on the Conservation of our Natural Resources, action was taken towards the creation of National and State Commissions, with co-operative action in view. How are our natural resources to be known but by the systematic study of them? The Association of State Geologists in session in Washington, May 12th ult., unanimously adopted the following resolutions, which show the value these men, all of whom are engaged in the study of their State's resources, place on the topographic map as the basis of all their work:

"Whereas, Our country, and the sovereign states composing it now face serious problems relating to the preservation of our natural resources, and,

"Whereas, These problems, of wisely administering our forests, our minerals, our soils, our water resources, are, to-morrow, to be the subject of a conference between the Governors of the various states and the President of the United States, and, "Whereas, We deem a contour-topographic map of our country so necessary to the intelligent solution of these and other equally important problems,

"Be it Resolved, That we most earnestly ask of State and Federal authorities in conference assembled, their support in securing such a map, and, since State and National interests are here so closely one, we most respectfully suggest: That State and Federal appropriations for topographic surveys be increased and that more immediately the Federal appropriation be increased for this work to meet the State appropriations now available.

"Be it Resolved, also, That a copy of these resolutions be presented to said Conference of the Governors with President Roosevelt with our greetings and respect."

No argument is needed to show the necessity of work by our State of the character suggested, nor the fact that to put off the same means but increased cost and in many cases a loss of data that can never be replaced. The work of the Second Geological Survey of Pennsylvania is a monument to the wisdom of the Legislature which inaugurated that work, and to all those who so faithfully carried on the work, in the field and laboratory.

The more time passes, the more we are impressed with the great value of that work, and its high quality under the conditions then existing. But neither Prof. Lesley, nor those engaged with him, ever considered the geology of Pennsylvania had been fully written, but on the contrary constantly urged the continuance of the work, and that it should be made a permanent bureau of the State government. Since the completion of the work of that Survey vast explorations have been made in all parts of the State, and new methods of geological work have been devised.

There has been greater advance in the science of geology during the past 25 years than in the century preceding, but above all, the development of the State along all material lines, and in all portions of it, has been so great, that the people need, and must have, the most exact knowledge attainable. From the very nature of the case satisfactory knowledge along geological lines can only be had by government work, and in this country such work must be under State auspices.

The concise progress report of the present co-operative geological work which forms the major part of this report, and which is in many ways the most valuable contribution yet made of the geology of Pennsylvania, but emphasizes the necessity of such a State survey.

Your Commissioners therefore recommend:

First: The creation of a permanent geological survey, which shall have complete authority to inaugurate and maintain a geological survey of the State, doing such work independently or in co-operation with the United States Geological Survey, or with the geological surveys of adjoining states; such survey to be more particularly of an economic nature, with the fullest development of the natural resources of the State as the ultimate object of the work.

Second: The continuance of the topographic work as at present, with an increase in the amount of the same, if such arrangement can be made with the United States Geological Survey.

Third: The publication of the results of such surveys in form and style suitable to and corresponding with the value of the subjects treated; the form of publication to vary with the character and completeness of the report.

Fourth: In order that such publications shall reach those most interested in and benefited by such studies, that a comprehensive plan of distribution be determined upon, and a liberal scheme of exchanges inaugurated and maintained.

Fifth: That appropriations be made commensurate with the foregoing recommendations.

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APPENDIX A.

LEGISLATIVE ACTS AND CONTRACTS.

AN ACT

To authorize the topographic and geological survey of the State in co-operation with the United States Geological Survey.

Section 1. Be it enacted, &c., That the Governor be and is hereby authorized to appoint a commission, to consist of three citizens of this State, to confer with the Director or Representative of the United States Geological Survey and to accept its co-operation with this State in the preparation and completion of a contour topographic and geological survey and map of this State, which is hereby authorized to be made. Said commission shall serve without pay, but all its necessary expenses shall, on approval by the Governor, be paid out of the State Treasury. Said commission shall have power to arrange with the Director or Representatives of the United States Geological Survey concerning this survey and map, its scale, method of execution, form, and all details of the work, in behalf of this State, and may accept or reject the work executed by the United States Geological Survey. And it is hereby provided that said map shall accurately show the outlines of all townships, counties and extensive wooded areas in this State, as existing on the ground at the time of the execution of these surveys; the location of all roads, railroads, streams, canals, lakes and rivers, and shall show by contour lines the elevation and depression of the surface of the country, also location of coal, oil, natural gas and clay bearing formations.

Section 2. For the prosecution of this survey, the sum of twenty thousand dollars is hereby appropriated, for the year one thousand eight hundred and ninety-nine, and twenty thousand dollars for the year nineteen hundred; and the Auditor General is hereby authorized to draw his orders on the State Treasury for such portions of these amounts as may be required, from time to time, from money in the treasury not otherwise appropriated, upon vouchers signed by two members of the commission; but it is hereby provided that these expenditures shall not be in excess of the amounts expended upon the same work by the United States Geological Survey from its own funds. The commission shall report to the Governor each year. For the purpose of making the surveys hereinbefore provided for, it shall be lawful for the persons employed in making the same to enter upon all lands within the boundaries of this State, but this act shall not be construed as authorizing any unnecessary interference with private rights.

Section 3. This act shall be in effect immediately upon its passage.

Approved—The 28th day of April, A. D. 1899.

WILLIAM A. STONE.

AGREEMENT.

BETWEEN THE TOPOGRAPHICAL AND GEOLOGICAL SURVEY COMMISSION OF THE STATE OF PENNSYLVANIA AND THE DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY, FOR THE CO-OPERATIVE TOPOGRAPHIC AND GEOLOGIC SURVEY OF THE STATE.

1. The preparation of the maps shall be under the supervision of the Director of the United States Geological Survey, who shall determine the methods of survey and map construction, in accordance with the act of Assembly of the State of Pennsylvania, entitled "An act to authorize the topographic and geologic survey of the State in co-operation with the United States Geological Survey," approved April 28, 1899.

2. The order in which in point of priority different parts of the State shall be surveyed shall be agreed upon in detail between said Commission and said Director.

3. The work shall be based upon the triangulation of the United States Coast and Geodetic Survey, and, wherever this triangulation is deficient, it shall be supplemented by said co-operative survey.

4. The survey shall be executed in a manner sufficiently elaborate to prepare a topographic map upon the scale of 1:62,500 exhibiting the hydrography, hypsography and public culture; said survey and map shall accurately show all township and county boundary lines (as established by the State laws at the time of their completion), and extensive wooded areas in this State as existing on the ground at the time of the execution of these surveys; the location of all roads, railroads, streams, canals, lakes and rivers, and shall show by contour lines the elevation and depression of the surface of the country, also on geologic maps and the location of the coal, oil, natural gas, clay-bearing and other geological formations. The said topographic maps shall be similar to the sheets already completed in this State, and the form of the final publications of the geological maps shall be the same as the Geological Atlas of the United States Geological Survey.

The preliminary field maps shall be on such a scale as said Director shall select to secure accuracy in the construction of the final map.

5. It is understood and agreed upon that the geological work shall follow the topographic survey as closely as consistent with economy and in accordance with modern scientific methods. The time of beginning this work to be agreed upon between the State

Survey Commission of Pennsylvania and the United States Geological Survey.

6. The hypsography shall be shown by contour lines with vertical intervals of 20 feet, and the heights of important points shall be determined and marked upon fixed and permanent bench marks in important and prominent places throughout the counties; also, correct meridian points shall be located at each county seat and records furnished to the said Commission.

7. For convenience, the United States Geological Survey shall, during the progress of the field work, pay the salaries of the persons employed therein, while the traveling, subsistence and field expenses shall be paid for the same time by the State. For office work on the map the salaries shall be divided between the two agreeing parties in such a way as to equalize all expenses, provided that the total cost to the State of Pennsylvania of the field and office work and expense of said Commission for the year 1899 and 1900 shall not be more than forty thousand dollars ($40,000), and, provided that the United States Geological Survey shall expend an equal amount.

8. During the progress of the work free access to the field sheets and records of the topographers and draughtsmen shall be afforded the State Commissioners for examination and criticism; and should they deem that the work is not being executed in accordance with this agreement, then the said Commissioners may, on formal notice, terminate this agreement.

9. The resulting maps shall fully recognize the co-operation of the State of Pennsylvania.

10. As the work is completed, the State Commissioners shall be furnished by the United States Geological Survey with photographic copies of the manuscript sheets; and, when the engraving, which is to be done at the cost of the United States Geological Survey, is completed, and at all times thereafter, when desired, the said Commission shall be furnished by the said Survey with transfers at cost of printing from the copper plates of the photographic sheets for use in printing editions of said maps.

Washington, D. C., July 12, 1899.

(Signed.) CHAS. D. WALCOTT,
Director, U. S. Geological Survey.

(Signed.) G. W. McNEES,
(Signed.) SIMON HARROLD,
(Signed.) FRED. D. BARKER,
Topographic Survey Commissioners.

APPENDIX B.

TRIANGULATION AND PRIMARY TRAVERSE.

The descriptions and positions published herewith result from the field work of the seasons of 1906-08.

PENNSYLVANIA.

TRIANGULATION STATIONS.

SMICKSBURG QUADRANGLE, JEFFERSON COUNTY.

Mr. Geo. T. Hawkins located two additional points for the control of this quadrangle in 1906. Positions are based upon stations Palmer and Rowland, U. S. Standard datum.

VALIER, JEFFERSON COUNTY, PENNSYLVANIA.

About midway between Perryville and Porter, in cultivated field on north side of road, owned by D. C. McGregor.

Signal: A tripod of sawed lumber.

Station mark: A marble post 30 by 7 by 7 inches set 30 inches in ground, in center of top of which is cemented a bronze triangulation tablet.

(Latitude, 40° 55′ 50.78″. Longitude, 79° 08′ 28.80″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Rowland,	23 35 00	203 33 00	4.03135
McGregor,	93 20 47	273 17 20	3.84864
Palmer,	317 13 30	137 20 00	4.31337

McGREGOR, JEFFERSON COUNTY, PENNSYLVANIA.

(Not occupied.)

About 1 mile southwest of McGregor postoffice on a prominent knoll which is covered with tall trees on top. The northeast slope is covered with brush 15 or 20 feet high and has one tall tree which is a prominent land mark on all sides except to the southwest.

Signal: Lone tree.

Station mark: Lone signal tree.

(Latitude, 40° 56′ 03.94″. Longitude, 79° 13′ 29.95″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Valier,	273 17 30	93 20 47	3.84864
Palmer,	306 22 22	126 32 09	4.41704
Rowland,	344 58 15	164 59 32	4.02618

PENNSYLVANIA.

TRIANGULATION STATIONS.

BEDFORD QUADRANGLE, BEDFORD COUNTY.

In October, 1906, Mr. G. T. Hawkins located 4 points for the control of this quadrangle, based upon stations Dunning and Everett, U. S. Standard datum.

DUNNING, BEDFORD COUNTY, PENNSYLVANIA.

On mountain locally known by that name, about 10 miles north of Mount Dallas and 4 miles south of New Enterprise, on timbered land owned by William Over.

Station mark: A bronze tablet marked "U. S. GEOLOGICAL SURVEY—PENNSYLVANIA," cemented in solid rock.

(Latitude, 40° 06′ 27.28″. Longitude, 78° 24′ 11.99″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Everett,	5 29 26.90	185 28 48.70	4.1679624
Pigeon,	75 11 05.30	255 04 57.38	4.1462093
Lohr,	96 24 45.84	276 12 52.34	4.4212414
Rattlesnake,	169 14 46.9	349 13 15.1	4.2553913
Duncan,	188 31 06.2	8 32 57.6	4.4391035
Russey,	207 49 44.6	27 52 15.0	4.0724843
Government,	305 21 47.6	125 25 37.3	4.0157449

EVERETT, BEDFORD COUNTY, PENNSYLVANIA.

On high summit of Tussey Mountain, about 3 miles south of Everett.

Station mark: A bronze tablet stamped "U. S. Geological Survey—Pennsylvania," cemented in solid rock.

(Latitude, 39° 58′ 32.14″. Longitude, 78° 25′ 11.35″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Dunning,	185 28 48.70	5 29 26.90	4.1679624
Pigeon,	132 23 12.40	312 17 43.16	4.2154627
St. Clair,	161 46 44.57	341 43 55.19	4.2993576
Lohr,	125 20 51.84	305 09 37.54	4.4830772
Government,	228 43 59.5	48 48 27.0	4.1180018
Smith,	260 22 54.7	80 33 28.2	4.3749415
Ray,	332 44 03.3	152 48 22.5	4.3219063

LOHR, BEDFORD-SOMERSET COUNTIES, PENNSYLVANIA.

Near boundary line between Somerset and Bedford counties, on top of the Allegheny mountain, 0.5 mile south of road between New Paris and Crum. 100 yards southeast of cluster of small trees.

Signal: A tripod of lumber covered with white cloth.

Station mark: A sandstone post 30 by 8 by 6 inches set 28 inches in ground with cross cut on top.

(Latitude, 40° 08′ 01.32″. Longitude, 78° 42′ 39.20″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Lone Tree,	24 40 05	204 38 47	3.83973
St. Clair,	265 43 22.16	85 51 48.00	4.2701046
Dunning,	276 12 52.34	96 24 45.84	4.4212414
Pigeon,	297 02 43.08	117 08 28.30	4.1540406
Everett,	305 09 37.54	125 20 51.84	4.4830772

LONE TREE, BEDFORD COUNTY, PENNSYLVANIA.

(Not occupied).

About 3 miles northwest of Fyan and about 3 miles southwest of Helixville, on top of Allegheny mountains. This point was not occupied, and only sighted from two primary points, Lohr and Pigeon, and therefore not to be depended upon. It is visible from St. Clair, but smoke prevented the sight being taken when St. Clair was occupied.

Signal: A lone pine tree, the western one of two.

Station mark: The lone pine signal tree.

(Latitude, 40° 04′ 37.6″. Longitude, 78° 44′ 41.0″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Lohr,	204 38 47	24 40 05	3.83973
Pigeon,	270 42 47	90,49 50	4.19272

PIGEON, BEDFORD COUNTY, PENNSYLVANIA.

About 3 miles northwest of Wolfsburg near north end of the Pigeon Hills, on land of J. E. Arnold, on west side of north and south rail fence between cornfield and brush.

Signal: A target in tall red oak, which is largest and most northerly of several trees in the fence row.

Station mark: A marble post 30 by 8 by 6 inches set 27 inches in ground 3.5 feet south of signal tree.

Latitude, 40° 04′ 30.79″. Longitude, 78° 33′ 43.29″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Lone Tree,	90 49 50	270 42 47	4.19272
Lohr,	117 08 28.30	297 02 43.08	4.1540406
St. Clair,	216 49 53.84	36 52 34.11	3.9922272
Dunning,	255 04 57.38	75 11 05.30	4.146209
Everett,	312 17 43.16	132 23 12.40	4.2154627

ST. CLAIR, BEDFORD COUNTY, PENNSYLVANIA.

About 1.5 miles southeast of St. Clairsville on top of spur and about halfway from base to summit. Station was located here instead of top because top is flat and covered with timber and would require much work to observe other points to south and southwest. Mr. Ross Slonaker, of St. Clairsville, knows location of station as it is near east corner of his land.

Signal: A target in pine tree.

Station mark: A tablet cemented in large stone under pile of rocks 6 feet base and 3 feet high.

Reference marks: Pine signal tree, azimuth 34° 56′, distant 16.4 ft.

(Latitude, 40° 08′ 45.62″. Longitude, 78° 29′ 34.53″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Pigeon,	36 52 34.11	216 49 53.84	3.9922272
Lohr,	85 51 48.00	265 43 22.16	4.2701046
Everett,	341 43 55.19	161 46 44.57	4.2993576

PENNSYLVANIA.

TRIANGULATION STATIONS.

FAIRFIELD, GETTYSBURG AND NEWVILLE QUADRANGLES, ADAMS AND CUMBERLAND COUNTIES.

In the fall of 1906 Mr. G. T. Hawkins, topographer, located 10 points for the control of these three quadrangles, based upon Gettysburg, Round Top, Fickle, Timber Hill and Roxbury, U. S. Standard datum.

BIG FLAT, ADAMS COUNTY, PENNSYLVANIA.

On the south end of the Big Flat about 0.25 mile south of county line where it makes a bend and 200 yards northeast of stone house owned by the State.

Signal: Target on large dead pine.

Station mark: Limestone 30 by 8 by 6 inches set 30 inches in ground. Tablet cemented in top.

Reference mark: Dead pine signal tree, azimuth 51° 37′, distant 41.0 feet.

(Latitude, 39° 59′ 33.45″. Longitude, 77° 24′ 04.02″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Green,	4 29 17	184 28 48	4.18522
Hammond,	237 07 20	57 13 12	4.18914
Fickle,	252 48 56	72 58 50	4.36014

BISHOP, ADAMS COUNTY, PENNSYLVANIA.

In Butler township, on a partly cleared hill owned by Mr. Bishop, 1.5 miles northwest of Biglerville.

Signal: A tripod built of poles and covered with cloth.

Station mark: A brown sandstone post 30 by 10 by 10 inches set 28 inches in ground; tablet cemented in top.

(Latitude, 39° 56′ 51.80″. Longitude, 77° 16′ 33.30″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Green,	53 49 03.09	233 43 45.09	4.1642000
Fickle,	223 41 38.17	43 46 42.17	4.2102363
Roundhill,	268 39 37	88 47 36	4.23354
Plainview,	291 04 22	111 07 55	3.92568
Round Top,	350 05 42.42	170 07 06.74	4.2600067

FICKLE, ADAMS COUNTY, PENNSYLVANIA.

On a partly cleared flat ridge near the northern extremity of the county, 2 miles north of Latimer postoffice. The station is 30 feet northeast of outcropping ledge on highest part of ridge on land of W. A. Bream.

Theodolite elevated 30 feet.

Station mark: A stone post 36 by 10 by 10 inches, set 30 inches in the ground, in center of top of which is cemented a bronze tablet marked "U. S. Geological Survey—Pennsylvania."

(Latitude, 40° 03′ 11.94″. Longitude, 77° 08′ 40.37″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Gettysburg—Round Top, ...	15 19 22.10	195 15 43.03	4.4876976
Bishop, ...	43 46 42.17	223 41 38.17	4.2102363
Green, ...	48 34 17.26	228 23 55.16	4.4871657
Big Flat, ...	72 58 50	252 48 56	4.36014
Hammond, ...	100 28 18	280 24 16	3.95701
South Mountain (Tree), ...	211 08 13.70	31 09 18.30	3.6627620
Round Top, ...	253 13 17.53	73 21 43.73	4.2889163
Pulpit, ...	322 16 43.84	142 24 17.92	4.4388914

GETTYSBURG—ROUND TOP, ADAMS COUNTY, PENNSYLVANIA.

The noted round knob, 3 miles south of Gettysburg. Theodolite mounted on upper floor of the iron observation tower, about 70 feet above ground.

Station mark: Center of stone foundation of tower.

(Latitude, 39° 47′ 10.54″. Longitude, 77° 14′ 21.74″.)

To Station—	Azimuth. ° ′ ″	Back azimuth. ° ′ ″	Log. Dist. Meters.
Fickle Hill, ...	195 15 43.03	15 19 22.10	4.4876976
Pulpit Rock, ...	252 19 22.35	72 30 33.80	4.4175998
Quirauk, ...	67 04 10	246 53 41	4.40570
Green, ...	122 00 13.09	301 58 13.37	4.2449713
Bishop, ...	170 07 06.74	350 05 42.42	4.2600067
Plainview, ...	197 39 09	17 41 17	4.19396
Round Hill, ...	217 22 50	37 29 08	4.36276

GREEN, ADAMS COUNTY, PENNSYLVANIA.

On land owned by State, 2 miles south of Chambersburg-Gettysburg pike on highest point of the Green ridge.

The timber was cleared from the summit and a red oak trimmed and left for signal.

Station mark: A bronze tablet cemented in solid rock.

Reference mark: The red oak signal tree, azimuth 347° 24′, distant 23.3 feet.

(Latitude, 39° 52′ 12.14″. Longitude, 77° 24′ 48.96″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Quirauk,	23 48 52	203 45 04	4.32305
Big Flat,	184 28 48	4 29 17	4.13522
Fickle,	228 23 55.16	48 34 17.26	4.4871657
Bishop,	233 43 45.09	53 49 03.09	4.1642000
Round Top,	301 53 31.37	122 00 13.09	4.2449718

PLAINVIEW, ADAMS COUNTY, PENNSYLVANIA.

On ridge 0.5 mile west of Plainview postoffice and 100 yards north of Jake Moss' house; 10 feet south of rail fence in the right of way of wagon road.

Signal: Cloth target in cedar tree.

Station mark: A marble post 30 by 7 by 7 inches set 28 inches in ground; bronze tablet cemented in top of post.

Reference marks: The cedar signal tree, azimuth 155° 00′, distant 3.8 feet.

(Latitude, 39° 55′ 13.42″. Longitude, 77° 11′ 02.17″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Round Top,	17 41 17	197 39 09	4.19396
Bishop,	111 07 55	291 04 22	3.92568
Roundhill,	249 43 38	69 47 48	3.99429

ROUND HILL, ADAMS COUNTY, PENNSYLVANIA.

(Not occupied).

About 15 miles northeast of Gettysburg on a heavily wooded summit with cleared field on southern slope.

Signal: The target erected by topographer who plane-tabled sheet.

(Latitude, 39° 57′ 04.12″. Longitude, 77° 04′ 32.13″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Roundtop,	37 29 08	217 22 50	4.36276
Plainview,	69 47 48	249 43 38	3.99429
Bishop,	88 47 36	268 39 37	4.23354

FLAT ROCK, CUMBERLAND COUNTY, PENNSYLVANIA.

(Not occupied).

About 5.5 miles northeast from Newville, on top of mountain east of the gap and about 1.5 miles by trail from summer hotel. Is a prominent white rock and the only bare spot seen from the Cumberland Valley.

Signal: Center of white rock.

Station mark: Same.

(Latitude, 40° 15′ 16.36″. Longitude, 77° 24′ 49.60″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Lee,	8 43 01	188 39 45	4.24484
Roxbury,	59 57 54	239 48 49	4.36348
Prospect,	338 59 41	159 01 06	3.94060

HAMMOND, CUMBERLAND COUNTY, PENNSYLVANIA.

In Penn township, on great pile of rock on top of ridge about 1.5 miles north of Henry Clay. An old road starts from Henry Clay and goes across mountain, a fork of which leads east along top of the ridge to within 200 yards of the station.

Signal: Tripod of poles covered with cloth.

Station mark: A bronze tablet cemented in rock.

(Latitude, 40° 04′ 05.15″. Longitude, 77° 14′ 56.22″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Big Flat,	57 13 12	237 07 20	4.18914
Fickle,	280 24 16	100 28 18	3.95701

LEE, CUMBERLAND COUNTY, PENNSYLVANIA.

About 2 miles northeast of Leesburg, on cultivated hill owned by Mr. Jacoby and is 0.25 mile north of Chambersburg and Carlisle pike.

Signal: A tripod of sawed lumber.

Station mark: A marble post 30 by 6 by 5 inches set 26 inches in the ground. In center of top of post is cemented a bronze triangulation tablet.

(Latitude, 40° 05′ 53.04″. Longitude, 77° 26′ 41.74″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Shippensburg,	19 55 11	199 53 53	3.91194
Roxbury,	108 31 22	288 23 30	4.26211
Flat Rock,	188 39 45	8 43 01	4.24484
Prospect,	212 02 56	32 05 34	4.03720

PROSPECT, CUMBERLAND COUNTY, PENNSYLVANIA.

In Prospect Hill Cemetery, 1 mile east of Newville.

Signal: A granite monument 25 feet high with figure on top which is the central monument of the Ahl family.

Station mark: Same.

(Latitude, 40° 10′ 52.36″. Longitude, 77° 22′ 37.40″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Lee,	32 05 34	212 02 56	4.03720
Roxbury,	81 36 54	261 26 24	4.36870
Flat Rock,	159 01 06	338 59 41	3.94060

SHIPPENSBURG, CUMBERLAND COUNTY, PENNSYLVANIA.

Two and one-half miles southeast of Shippensburg in cleared field of John Hosfeld.

Signal: A tripod of sawed lumber.

Station mark: A marble post 36 by 6 by 6 inches set 33 inches in the ground. In center of top of post is cemented a bronze triangulation tablet.

(Latitude, 40° 01′ 44.15″. Longitude, 77° 28′ 39.06″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Timber Hill,	86 50 46	266 48 31	3.69689
Roxbury,	132 47 26	312 40 50	4.29761
Lee,	199 53 53	19 55 11	3.91194

ROXBURY, FRANKLIN COUNTY, PENNSYLVANIA.

(Not occupied).

On the first ridge northwest of valley on well known knob of that name. All timber cleared summit and one tree left for signal.

Station mark: Lone signal tree.

Reference mark: Tablet cemented in solid rock 4 feet southeast of signal.

(Latitude, 40° 09′ 00.74″. Longitude, 77° 38′ 54.28″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Chambersburg,	2 36 35	182 36 06	4.37343
Strasburg,	37 25 40	217 21 49	4.14580
Timber Hill,	324 59 40	145 04 01	4.22450
Flat Rock,	239 48 49	59 57 54	4.36348
Prospect,	261 26 24	81 36 54	4.36870
Lee,	288 23 30	108 31 22	4.26211
Shippensburg,	312 40 50	132 47 26	4.29761
Timber Hill,	324 59 40	145 04 01	4.22450

TIMBER HILL, FRANKLIN COUNTY, PENNSYLVANIA.

On hill of same name about 1.5 miles south of Shippensburg on land of Mr. John Plaster.

Station mark: A lone hickory tree near west edge of a cleared field.

Reference mark: A cross cut in limestone 11.4 feet distance from signal, bearing S. 38° W.

(Latitude, 40° 01′ 35.22″. Longitude, 77° 32′ 08.61″.)

To Station—	Azimuth.	Back azimuth.	Log. Dist.
	° ′ ″	° ′ ″	Meters.
Chambersburg,	47 22 24.60	227 17 34.80	4.1629694
Parnell,	66 33 16.13	246 20 39.85	4.4839378
Strasburg,	98 18 45.67	278 10 33.96	4.2627043
Roxbury,	145 04 01	324 59 40	4.22450
Shippensburg,	266 48 31	86 50 46	3.69689

PENNSYLVANIA.

PRIMARY TRAVERSE.

McCALL FERRY AND QUARRYVILLE QUADRANGLES, CHESTER AND YORK COUNTIES.

The following geographic positions on U. S. Standard datum for the control of the McCall Ferry and Quarryville quadrangles, were determined from primary traverse run by F. J. McMaugh, junior topographer, in 1907. The lines were run as follows:

Line No. 1 begins with adjusted position at Columbia (Kendall) and follows highways east via Creswell and Millersville to a point near Willow street, thence south via Herrville and Truce to Rawlinsville triangulation station and continues south via Liberty Square to Dunmore, thence along the Columbia and Port Deposit Railroad to Peters Creek, where it crosses the Susquehanna river to Peach Bottom and continues southeast along the highways and is tied to Pennsylvania-Maryland state line boundary post at Delta (Hall).

Line No. 2 begins at Peters Creek and continues east along highways via Wakefield and Oak Hill to adjusted position at Oxford (Kendall).

Line No. 3 begins with adjusted position at Octoraro (Kendall) and follows highways west via Collins and Buck and is tied to line No. 1 near Rawlinsville triangulation station, Coast and Geodetic Survey.

McCALL FERRY QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Columbia, intersection of Union and Fourth Sts., ...	40 01 50.3	76 29 56.1
Columbia, 1 mile southeast of, forks of roads southeast and east, ...	40 01 21.0	76 29 32.4
T road to northeast, ...	39 59 53.2	76 28 24.7
Bridge over small stream, 600 feet north of, 4 corners,	39 58 57.2	76 27 49.4
Brick church, 1.75 miles northwest of, T road east, ..	39 58 27.6	76 27 28.1
Brick church, 0.25 mile southwest of, T road south, ..	39 57 41.3	76 26 16.2
Brick church, center of front door of, ...	39 57 52.1	76 26 10.3
Brick church, 1 mile northeast of, forks, roads northeast and northwest, ...	39 58 21.0	76 25 15.5
Brick church, 2 miles northeast of, 4 corners, ...	39 58 33.8	76 24 24.3

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Three corners T road to south, signboard reads "Cresswell 3 mi., Letort 1 mi., Millersville 2½ mi., Safe Harbor 5½ mi."	39 59 16.4	76 23 37.9
Millersville, 0.25 mile east of, T road south, sign reads "Cresswell 5 mi., Letort 3 mi., Millersville ¼ mi., Safe Harbor 5½ mi."	39 59 37.5	76 22 15.8
Millersville, in south face at southwest corner of Laundry and Carpenter shop building of the Pa. State Normal school; aluminum tablet stamped "Prim. Trav. Sta. No. 3, 1907 PENNSYLVANIA,"	39 59 52.5	76 21 22.2
Millersville, 0.75 mile southeast of, T road to west, ...	39 59 15.6	76 21 31.3
Covered bridge over Conestoga River, 0.75 mile southeast of, 4 corners, 25 feet northeast to corner of white fence, 22 feet southwest to large sycamore tree,	39 58 32.9	76 21 00.1
Electric railroad crossing, center of track,	39 58 52.8	76 19 58.0
Danville, 0.5 mile southwest of, 4 corners, pike crossing east and west road, Lancaster 5 mi., Safe Harbor 5 mi., West Willow 2 mi."	39 58 51.7	76 19 04.5
Lancaster and Reading Narrow Gauge Railroad, center of track,	39 59 01.3	76 17 36.4
Lancaster and Reading Narrow Gauge Railroad, 0.75 mile northeast of, pike crossing east and west road, (known as Mylins 4 corners), 44 feet northwest to signboard, 27 feet southeast to telegraph pole, 39 feet northeast to telegraph pole; west rail of trolley track,	39 59 11.2	76 16 53.0

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR EAST BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Willow street, 0.75 mile north of, 4 corners,	39 58 14.0	76 16 24.4
Willow street, front door of brick church,	39 57 40.7	76 16 09.4
Herrville, crossroads,	39 56 47.6	76 15 26.3
Herrville, 1.25 miles south of, 4 corner, 19 feet east to mailbox, 57 feet west to sign Lancaster 10 mi., Port Deposit 25 mi., Providence 2 mi., Martin Forge 5 mi.,	39 55 40.8	76 15 08.3
Smithville, in top stone, 51.3 feet north of south end of retaining wall under stone arch bridge over highway and creek; aluminum tablet stamped "Prim. Trav. Sta. No. 4, 1907 PENNSYLVANIA,"	39 55 31.8	76 15 05.4
Truce, 0.6 mile west of, crossroads,	39 53 13.0	76 15 00.4
Rawlinsville triangulation station, on land of Adam Lefevre of Lampeter Square. In Providence township, 14 mi. from Lancaster, 5 miles from McCall Ferry, 8 mi. from Quarryville. The crossroads upon which station is situated (1879) has been closed and fence lines will be moved so that distance measured to it hereafter may not be correct. Station mark:		

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Underground mark is a hew limestone, in center of which is iron foxtail, ¾ in. diam., 6 in. long. Block is 3 ft. below surface, under a cut stone tale slate, straited, 6 in. square and so planted as to project 2 in. above surface with its angles on the meridian and diagonal cuts across, ...	39 53 09.54	76 15 58.37
Rawlinsville, crossroads 60 feet northeast to corner store, 41 feet northwest to corner of brown fence, 36 feet south to corner of white fence, 8 feet south to trolley track, ...	39 52 56.6	76 16 08.4
Rawlinsville, 1.7 miles south of, crossroads, 16 feet south to signboard, 27 feet southwest to post at corner fence, 71 feet southwest to center of grass plot, signboard reads "Quarryville 6 mi., McCall Ferry 4 mi., Rawlinsville 1½ mi., Liberty Square 2 mi."	39 51 31.8	76 16 13.9
Rawlinsville, 2.5 miles south of, T road north, ...	39 50 45.3	76 16 21.6
Four corners, signboard reads "Chestnut Level, 3 mi., McCall Ferry 5 mi., Rawlinsville 4 mi."	39 49 50.6	76 16 26.5
Mt. Holly schoolhouse, 0.75 mile north of, crossroads, 27 feet northeast to corner fence, 22 feet northwest to oak, 25 feet southwest to signboard "Fishing Creek 3 mi., Rawlinsville 4 mi., Chestnut Level 3 mi., McCall Ferry 5 mi."	39 49 10.3	76 16 25.5
Mt. Holly schoolhouse, 0.25 mile south of, forks of roads west and southwest, sign reads Fishing Creek 2 mi., ...	39 48 20.8	76 16 16.6
Riverside schoolhouse, 0.6 mile north of, forks of roads north and west, ...	39 47 53.3	76 15 59.0
Fishing Creek, center of wooden bridge over, ...	39 47 29.0	76 15 50.0

GEOGRAPHIC POSITIONS ALONG COLUMBIA AND PORT DEPOSIT RAILROAD NEAR BENTON.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Benton station, 200 feet north of, T road east, ...	39 46 37.1	76 15 08.3

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR SOUTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Peach Bottom, T road north, sign reads York 32 mi.,..	39 45 22.2	76 16 11.0
Peach Bottom, 2 miles southwest of, crossroads, sign reads "Darlington 10 mi., Delta 2 mi., Peach Bottom 2 mi."	39 44 21.0	76 17 23.0
South Delta, 1.75 miles northeast of, cross roads, ...	39 44 02.5	76 18 31.8
South Delta, Pennsylvania-Maryland state line boundary post, ...	39 43 16.20	76 20 09.73

Magnetic declination, north border, 6° 44′ West.
East border, 6° 31′ West.
South border, 6° 16′ West.

QUARRYVILLE QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR WEST BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Smithville, 0.5 mile southeast of, 4 corners crossroads,	39 55 02.6	76 14 44.8
Truce, 1 mile northwest of, T road west, 50 feet north of T road east, signboard reads "Rawlinsville 3 mi."	39 54 13.8	76 14 31.7
Truce, crossroads, sign reads "Lancaster 13 miles, Buck 1½ miles, New Providence 3 mi."	39 53 25.0	76 14 17.6

GEOGRAPHIC POSITIONS ALONG THE COLUMBIA AND PORT DEPOSIT RAILROAD NEAR PETERS CREEK.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Whitaker station, front door of, ...	39 45 53.9	76 14 30.7
Peters Creek, in coping stone at east end of south abutment of Columbia and Port Deposit railroad bridge over; aluminum tablet stamped "Prim. Trav. Sta. No. 5, 1907 PENNSYLVANIA,"	39 45 22.8	76 14 05.7

GEOGRAPHIC POSITIONS ALONG HIGHWAYS, PETERS CREEK TO OXFORD.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Peters Creek, 1.75 miles northeast of, crossroads, sign reads "Fairfield 2 mi., Pleasant Grove 22 mi., Oxford 13 mi., Peach Bottom 2 mi."	39 45 54.6	76 12 29.7
West Brook station, Lancaster and Oxford Southern railroad crossing narrow gauge, center of track, ...	39 46 31.2	76 11 37.2
West Brook station, 0.8 mile east of, crossroads at store, 52 feet southeast to corner store, 30 feet northeast to telegraph pole and sign Lancaster 24 mi., Port Deposit 14 mi., Oxford 12 mi., Peach Bottom 3 mi.," 35 feet southwest to corner of fence, ...	39 46 25.9	76 10 46.2
Four corners, 55 feet southeast to telephone pole, 33 feet southwest to corner of hedge fence, ...	39 46 36.0	76 09 11.0
Oak Grove, 4 corners, signboard reads "Fulton House 2 mi., Fairmont 5 mi., Peach Bottom 7 mi., Oxford 10 mi.,"	39 46 35.9	76 08 29.8
Poplar Grove schoolhouse, T road north, sign board reads "Conowing Springs 8 mi., Oxford 9 mi.," etc., ..	39 46 41.0	76 07 12.7
Oak Hill, crossroads, sign reads "Peach Bottom 9 mi., Oxford 8 mi.," etc., ...	39 46 56.0	76 05 24.9
Oak Hill, in sandstone boulder in southeast corner of crossroads; aluminum tablet stamped "Prim. Trav. Sta. No. 6, 1907 PENNSYLVANIA,"	39 46 55.9	76 05 24.6
Oak Hill, 1 mile southeast of, at Summer Hill schoolhouse 4 corners, ...	39 46 26.2	76 04 27.6

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Octoraro Creek, center of covered bridge over line between Lancaster and Chester counties, ...	39 46 02.9	76 03 50.5
Glenroy post-office, signboard in center of grass plot,	39 46 00.5	76 02 59.8
Glenroy post-office, 1.25 miles northeast of, 4 corners, sign reads "Oxford 3 mi., Oakhill 4 mi.,"	39 46 21.1	76 01 45.2
Hopewell schoolhouse, front door of, ...	39 46 44.6	76 01 06.5
Oxford, 0.75 mile southwest of, railroad crossing, center of track, ...	39 46 47.7	75 59 25.1
Oxford, ...	39 47 05.8	75 58 45.0

GEOGRAPHIC POSITIONS ALONG HIGHWAYS, OCTORARO WEST TO BUCK.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Octoraro, in south face, near southwest corner of brick store and post-office building, aluminum tablet stamped "Prim. Trav. Sta. No. 7, 1907, PENNSYLVANIA,"	39 52 18.0	76 00 17.2
Octoraro, 1.5 miles west of, crossroads, sign reads "Steelville 4 mi., Kirkwood 3 mi., Oxford 6 mi., ...	39 52 27.5	76 01 59.2
Pleasant Grove schoolhouse, front door of, ...	39 52 39.9	76 02 58.3
Bartville, 0.5 mile southeast of, crossroads, sign reads "Kirkwood 3 mi., Jackson's Mill 2 mi., Steelville 5 mi., Bell Road 2 mi.,"	39 53 14.9	76 03 45.6
Bartville, crossroads (Cotters Corners), 50 feet north to southeast corner of post-office, 63 feet west to corner picket fence, 41 feet south to corner wire fence, ...	39 53 29.1	76 04 05.4
Bartville, 0.75 mile northwest of, forks of roads northwest and south, ...	39 53 47.7	76 04 48.9
Bartville, 1.5 miles northwest of, T road south, ...	39 53 47.4	76 05 37.1
Collins post-office, 1.5 miles northeast of, T road north,	39 53 30.1	76 06 44.4
Collins post-office, crossroads, 42 feet north to corner porch of store and post-office, 58 feet northwest to telegraph pole, ...	39 52 48.7	76 07 58.4
Collins post-office, in west face at northwest corner of Harmoner school house; aluminum tablet stamped "Prim. Trav. Sta. No. 8, 1907 PENNSYLVANIA," ..	39 52 49.1	76 07 57.0
Collins postoffice, 0.75 mile northwest of, crossroads,..	39 53 17.3	76 08 34.6
Quarryville cemetery, crossroads, ...	39 53 01.6	76 09 38.7
Buck, 1.75 miles northeast of, forks of roads southwest and west, sign reads "Hopkins Mill 2 mi., Oak Bottom 2 mi., Buck 2 mi.,"	39 52 40.6	76 10 50.0
Buck, 1 mile northeast of, crossroads, sign reads "Quarryville 2 mi., Buck 1 mi., Hopkins Mill 1.5 mi., Lancaster 14 mi.,"	39 52 40.6	76 12 46.8
Buck, crossroads, 50 feet south to telephone pole near large poplar, 66 feet east to corner large white barn,	39 52 21.4	76 13 44.2

Magnetic declination, West border, 6° 31′ West.
South border, 6° 24′ West.
North border, 5° 57′ West.

PENNSYLVANIA.

BELLEFONTE, PHILIPSBURG AND SNOWSHOE QUADRANGLES, CENTRE AND CLEARFIELD COUNTIES.

The following geographic positions on U. S. Standard were determined from primary traverse run by C. B. Kendall in October, 1907. The line begins at Morrisdale triangulation station and follows the mountain division of the Pennsylvania Railroad south to Gardner station, thence east along highways via Hannah station to Gatesburg, where it turns north along highways via Martha station to the summit of the Allegheny mountains, and continues north across the plateau, following trails to a point on the New York Central and Hudson River Railroad about 2 miles east of Gorton Heights station. Thence west along the New York Central and Hudson River Railroad to Peall station and continues west along highways via Kylertown to Pardee triangulation station.

For the control of the Bellefonte quadrangle the line begins at the point 2 miles east of Gorton Heights station and follows the New York Central and Hudson River Railroad to Gillintown station thence east along highways via Snowshoe, Rhooda station and Yarnell to Curtin station. Thence south along the Pennsylvania Railroad via Milesburg and Bellefonte to Peru station and continues south along highways to a point 1.5 miles south of Linden Hall where it turns west along highways via Bloomsdorf station to adjusted position at Gatesburg.

Two additional lines were run, one beginning at Philipsburg and running east along highways via Beaver Mills to tie point at summit of Allegheny mountains. The other begins at Milesburg and follows the Bald Eagle Valley Division of the Pennsylvania Railroad southwest via Unionville and Martha to Hannah, tieing with the main circuits at the last two points.

PHILIPSBURG QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG PENNSYLVANIA RAILROAD, MORRISDALE TO GARDNER.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Morrisdale triangulation station. (Not occupied.) The tower of the large brick school building at Morrisdale, 4 miles north of Philipsburg. Station mark: Center of tower,	40 56 51.88	78 13 26.61

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Morrisdale, junction of streets southeast and southwest at John W. Howe's store, 35 feet south to telephone pole, 10 feet east to trolley track, ...	40 56 40.0	78 13 40.6
Loch Lomond Junction, at the " R U" tower, crossing of New York Central and Hudson River R. R. and Pennsylvania R. R., ...	40 55 04.3	78 12 39.8
Philipsburg, 0.75 mile northeast of, road crossing 75 feet southwest of trestle No. 208, center of track, ...	40 54 18.5	78 13 14.8
Philipsburg station, 75 feet south of; West Presqueisle street crossing, center of main track, ...	40 53 43.1	78 13 24.3
Steiners station, 75 feet northeast of, road crossing; center of main track, ...	40 53 21.9	78 13 30.0
Moshannon Creek, Pennsylvania railroad bridge over; center of pier, ...	40 52 50.1	78 14 10.5
Boynton station, 0.25 mile southwest of, road crossing; east main, or center track, ...	40 51 57.7	78 14 52.0
Osceola Mills station, 200 feet northwest of; in west edge of grass plot lying between the Tyrone-Clearfield and the Moshannon branches of the Pennsylvania Railroad, and about 50 feet southeast of the triangle at junction of the Osceola-Sandy Ridge road and Curtin street; iron post stamped "Prim. Trav. Sta. No. 1, 1907 PENNSYLVANIA,"	40 50 58.3	78 15 47.6
Osceola Mills station, 1 mile southeast of; road crossing at switch to coal mine, north rail of south track,	40 50 11.0	78 15 45.3
Powellton station, 1100 feet north of; road crossing on curve near row of 6 houses, west rail of west track,	40 49 44.1	78 14 38.2
Retort station, 30 feet south of, road crossing, center between main tracks, ...	40 48 59.3	78 14 08.2
Sandy Ridge station, 200 feet south of; road crossing, east rail of west track, ...	40 48 20.9	78 13 37.4
Summit station, opposite operators tower; center of east track, ...	04 47 20.2	78 14 22.4
Milepost No. 12, center of track opposite, ...	40 46 31.2	78 14 32.6
Mt. Pleasant station, center of track opposite water tank, ...	40 45 32.7	78 14 49.5
Milepost No. 9, center of track opposite, ...	40 45 16.1	78 13 32.1
Gardner station, 210 feet west of; 95 feet south of milepost No. 8, on north edge of road at bend to southwest; top of milepost 8 bears N. 61° W. distant 94.6 feet; southwest corner of waiting shed bears N. 86° 15′ E., distant 211.4 feet; iron post stamped "Prim. Trav. Sta. No. 2, 1907 PENNSYLVANIA,"	40 44 36.3	78 13 46.2

GEOGRAPHIC POSITIONS FROM GARDNER EAST ALONG HIGHWAYS VIA HANNAH TO GATESBURG.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Gardner station, 1.25 miles northeast of; T road west, 70 feet northeast to bridge over Arnelgh Run, 30 feet southwest to corner of fence, ...	40 44 50.5	78 12 25.4

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Gardner station, 2.5 miles northeast of; 4 corners, Gardner-Hannah road crossing the Philipsburg-Tyrone pike, 25 feet southeast to W. H. Beigler's mail box, 25 feet northeast to chestnut tree, ...	40 45 55.6	78 11 42.7
Second class road to southeast, center of main road, 15 feet southeast to double chestnut oak, 40 feet northeast to boulder, ...	40 46 42.9	78 10 56.1
Fowler station, about 2.5 miles northwest of, forks of roads northeast and southeast, point of triangle; 30 feet west to bridge over Vaughn's Run, 20 feet southwest to double oak, ...	40 47 12.9	78 09 34.4
Fowler station, 2 miles northwest of, 4 corner roads southeast, northeast and southwest; second class road to west, forked oak, ...	40 46 45.7	78 08 45.8
Fowler station, 1.5 miles northwest of, forks of road, signpost in center of triangle, post marked "To Fowler 1.5 mi., Sandy Ridge 8 mi., Hannah 2 mi.,"	40 46 28.5	78 08 19.8
Fowler station, 800 feet northeast of; on north edge of the Tyrone-Bellefonte old plank road, in northwest corner of intersection with the Sandy Ridge road; iron post stamped "Prim. Trav. Sta. No. 3, 1907 PENNSYLVANIA,"	40 45 26.5	78 06 45.5
Hannah station, road crossing Pennsylvania Railroad, center between tracks, ...	40 45 58.4	78 05 45.4
Hannah station, 1.5 miles east of, forks of road on top of ridge, road south, second class road west; center of triangle, 40 feet southeast to chestnut oak, 35 feet southwest to chestnut oak, ...	40 45 56.1	78 04 29.0
Loveville, 1 mile north of, 4 corners; intersect Half Moon Valley pike and Loveville-Hannah road, ...	40 45 45.4	78 03 44.1
Loveville, T road to north at store, 25 feet northwest to corner store porch, 25 feet east to poplar tree at corner of garden fence, ...	40 45 08.0	78 03 25.9
Loveville, 1 mile east of, T road west; center of triangle, 25 feet southwest to signboard; "Tyrone 13 mi," 25 feet east to post and rail fence, ...	40 45 12.9	78 02 16.3
Gatesburg, 1.25 miles west of, T road north, center of triangle, 25 feet east to sign boards, "Maringo 1 mi., Loveville 2 mi., Gatesburg 1 mi.,"	40 44 39.8	78 01 45.3
Gatesburg, cross streets opposite the Lutheran Church, center of intersection, ...	40 44 41.0	78 00 18.3
Gatesburg, in southeast corner of cross streets, 125 feet west of Gatesburg Lutheran church, iron post stamped "Prim. Trav. Sta. No. 4, 1907 PENNSYLVANIA,"	40 44 41.0	78 00 18.4

GEOGRAPHIC POSITIONS ALONG HIGHWAYS FROM GATESBURG NORTH.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Stormstown, 0.7 mile southeast of; fork of roads east and southeast, 35 feet south to oak tree, 30 feet north to sign post, "State College 9 mi., Pinegrove 8 mi.,"..	40 47 11.0	78 00 23.4
Stormstown, T road southeast, center of Halfmoon pike, 140 feet west to T road north, 40 feet southeast to northwest corner of Burket's store, ...	40 47 36.8	78 00 59.5
Martha station, 300 feet west of, road crossing the Bald Eagle Valley Railroad, center of main track, ...	40 49 59.7	78 00 27.8
Martha, 1.5 miles north of; forks of roads north and northwest, southeast point of triangle, 20 feet east to small thorn tree; 12 feet south to wire fence, ...	40 51 17.6	78 00 47.2
Black Oak Schoolhouse, 0.25 mile east of, forks of road on top of hill, south, east and west, center of triangle, ...	40 52 20.9	78 00 35.7
Blackoak schoolhouse, on south edge of road about 3 miles north of Martha and 0.75 mile south of summit Allegheny Mountains, at northeast corner of schoolhouse; iron post stamped "Prim. Trav. Sta. No. 5, 1907 PENNSYLVANIA,"	40 52 17.7	78 00 47.1
Blackoak schoolhouse, 0.7 mile north of; on mountain side, junction of Philipsburg-Bellefonte pike and road south to Martha, 25 feet south to Chestnut oak and sign "Martha 5 mi., Julian 5 mi.,"	40 52 50.2	78 00 39.8
Blackoak schoolhouse, 1 mile northwest of; at summit of the Allegheny Mountains, center of Philips-Bellefonte pike; 25 feet north to oak tree stump, 40 feet east to old road north, ...	40 52 57.4	78 01 14.4

GEOGRAPHIC POSITIONS ALONG OLD ROADS AND TRAILS.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Allegheny summit, 1 mile northeast of; forks of roads east and northeast, 30 feet south to slim dead pine, 50 feet northeast to chestnut, ...	40 53 30.3	78 00 16.7
Rattlesnake pike, 2 miles northwest of, 0.5 mile north of Benner Run, on east edge of road, large granite boulder, cross on highest point of, ...	40 56 16.6	78 00 02.8
Benner Run, top of ridge north of; at junction of the Lober and Beacher old dinky Railroad grade leading south from mouth of Rock Run, and old timber trail leading north from the Rattlesnake pike via Benner Run; rock cairn 3 feet high, ...	40 56 43.9	78 00 10.6
New York Central and Hudson River Railroad, 3 miles south of; in Lober and Beachy dinky old grade at east and west old road crossing about 800 feet east of head of hollows, 30 feet east to cross cut on pine tree, 40 feet north to oak tree blazed and scribed thus: X P— rock cairn 3 feet high, ...	40 57 24.9	78 00 06.9

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Lober and Beacher old camp grounds; old road crossing the dinky railroad grade, center of old grade; 35 feet west to cross cut on oak tree,	40 57 48.5	78 00 15.2
New York Central and Hudson River Railroad; 0.9 mile south of; center of old dinky bridge over Rock Run,	40 59 10.7	78 00 17.2

GEOGRAPHIC POSITIONS ALONG THE NEW YORK CENTRAL AND HUDSON RIVER RAILROAD, GORTON TO PEALE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Gorton, 1.5 miles east of, center of girder bridge over Little Moshannon creek,	40 59 48.5	78 00 24.8
Gorton station, 1,000 feet east of; at west end of coke ovens, road crossing, south rail, main track,	40 59 37.6	78 02 06.4
Gorton station, 70 feet east of operator's office, 30 feet north of center of main track; southeast corner of operator's office bears N. 69° W., distant 66.6 feet; southwest corner of section foreman's house bears N. 87½° E., distant 60.5 feet; southwest corner in front yard of section foreman's house; iron post stamped "Prim. Trav. Sta. No. 6, 1907 PENNSYLVANIA,"	40 59 42.6	78 02 19.2
Peale station, 0.75 mile northeast of, southeast entrance to Peale tunnel, center of track,	40 59 16.1	78 04 01.0
Peale station, road crossing, center of main track,	40 59 27.5	78 04 50.3

GEOGRAPHIC POSITIONS ALONG HIGHWAYS.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Peale (town), 300 feet southeast of hotel; center of road on fill over small stream at 5 corners,	40 59 53.5	78 04 52.9
West Climer, 0.6 mile east of; at watering trough, T road north, 60 feet east to watering trough, 15 feet north to sign "Drifting 3 mi.,"	41 00 10.0	78 06 05.2
West Clymer, cross streets at Swedish Church, 50 feet southeast to cupola of church, 30 feet northeast to stump and telephone pole, 35 feet northwest to sign "Kylertown 4 mi.,"	41 00 09.9	78 06 42.9
West Climer, 1 mile west of; T road to east at Pleasant Hill schoolhouse, 60 feet west to schoolhouse door, 40 feet north to pine tree,	41 00 08.9	78 07 53.7
West Climer, 1 mile west of, in east face at northeast corner of foundation of Pleasant Hill schoolhouse, aluminum tablet stamped "Prim. Trav. Sta. Mo. 7, 1907, PENNSYLVANIA,"	41 00 08.8	78 07 54.5
Kylertown, 1.5 miles southeast of; 4 corners crossroads, 20 feet south to signpost "Kylertown 1.5 mi., Viaduct 4.5 mi., Grassflat 2.75 mi., Winburn 1.5 mi.," 30 feet west to telephone pole,	40 59 10.1	78 08 29.7

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Kylertown, cross streets at hotels, 35 feet northeast to corner of Commercial Hotel, 35 feet southwest to corner of old Kyler House,	40 59 36.7	78 10 03.2
Kylertown, 1 mile southwest of, Pardee triangulation station, aboot 400 feet north of; 5 corners, center of triangle; 60 feet southwest to sign Grahamtown road 1 mile,	40 58 58.6	78 10 36.0
Pardee triangulation station; in Morris Township, 1 mile south of Kylertown, 2 miles north of Munson, on property of the Pardee Coal Company, 20 feet east of road at a point 150 yards south of forks of road. Station mark: An oak tree trimmed up, 10 feet east of north and south fence and 2 feet south of each and west fence,	40 58 54.96	78 10 34.43

GEOGRAPHIC POSITIONS ALONG HIGHWAYS FROM PHILIPSBURG EAST.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Philipsburg station, 1 mile northeast of; bridge over Cold Stream, 450 feet east of, T road to west; center of triangle,	40 54 06.5	78 12 31.1
Philipsburg station, 2 miles northeast of; 4 corners at One Mile Run, 400 feet south of coal mine, 30 feet west of center of bridge over One Mile Run, 80 feet southeast to telephone pole,	40 54 19.8	78 11 50.3
Top of ridge between Cold Stream and Black Bear Run, 500 feet west of; forks of road to northeast, 25 feet east to forked chestnut, 60 feet northwest to two chestnut trees,	40 53 59.4	78 09 54.8
Black Bear Run, center of highway bridge over,	40 54 04.3	78 09 13.9
Black Bear and Six Mile Runs, at summit between; old north and south second class road crossing pike, 30 feet southeast to clump of 3 chestnut trees, 25 feet southwest to oak,	40 54 09.3	78 07 45.4
Artic Springs, center of pike at entrance to grounds, 25 feet south to gateway, 50 feet northwest to clump of 3 pines,	40 54 23.2	78 07 08.5
Six Mile Run, center of highway, bridge over,	40 54 33.0	78 06 16.4
Six Mile Run, 1.25 miles east of, 4 corners at northeast edge of clearing, T road to north, second class fork of road southeast, 15 feet southwest to corner of wire fence, 25 feet north to corner of wire fence,	40 54 34.5	78 04 44.6
Black Moshannon schoolhouse, 420 feet east of; bridge over Black or Little Moshannon creek, 260 feet west of, in sandstone ledge or north edge of Philipsburg-Bellefonte pike, 30 feet north of junction with public roads northwest to Peale; bronze tablet stamped "Prim. Trav. Sta. No. 15, 1907 PENNSYLVANIA,"	40 54 55.1	78 03 39.7

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Old Beaver Mills Company store, 1,200 feet south of; forks at bend of pike to east, second class road to south, 25 feet south to gate, 65 feet east to corner of stone foundation to old house, 40 feet north to corner of cemetery fence, ...	40 53 20.4	78 02 25.1

GEOGRAPHIC POSITIONS ALONG PENNSYLVANIA RAILROAD, MARTHA TO HANNAH.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Milepost No. 16-39, 100 feet west of; second class road crossing, center of track, ...	40 49 16.5	78 01 31.1
Port Matilda station, 50 feet west of; public road crossing, center of main track, ...	40 47 51.0	78 03 05.0
Port Matilda station, 250 feet northwest of, in top of west wing wall to south abutment of highway bridge over Bald Eagle Creek, aluminum tablet stamped "Prim. Trav. Sta. No. 16, 1907 PENNSYLVANIA," ..	40 47 52.8	78 03 07.5
Port Matilda, 1 mile southwest of, milepost 13, 1,000 feet west of, second class road crossing, center of track, ...	40 47 14.9	78 03 55.8
Hannah, 1 mile northeast of, 500 feet west of milepost 12, second class crossing, center of track, ...	40 46 45.9	78 04 45.7
Hannah station, road crossing Pennsylvania Railroad, center of between tracks, ...	40 45 58.42	78 05 45.40

Declination, west border quadrangle, 5° 04′ West; South border, 5° 26′ West; East border, 5° 53′ West; North border, 5° 29′ West; center of sheet, 5° 32′ W.

SNOESHOE QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Milepost "J S 52," center of track opposite, ...	41 00 14.2	77 59 03.2
Milepost "J S 51," center of track opposite, ...	41 00 52.5	77 58 47.3

GEOGRAPHIC POSITIONS ALONG HIGHWAYS.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Gillintown station, 0.5 mile east of, T road east, 30 feet southwest to apple tree, 25 feet southeast to telephone pole at corner of fence, ...	41 01 49.8	77 59 07.8
Snowshoe, 0.8 mile northwest of, T road north, 40 feet northeast to large oak by fence, 60 feet west to telephone pole, ...	41 01 48.2	77 57 49.0
Snowshoe, 1,200 feet south of station, 100 feet north of Methodist church, crossing of Gillintown-Snowshoe pike and State road, 15 feet southeast to drain abutment, 20 feet northeast to drain abutment, ...	41 01 37.5	77 57 05.5

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Snowshoe, 0.9 mile east of, T road to south, 15 feet north to oak, 25 feet south to farm gate,	41 01 37.5	77 56 09.1
Snowshoe, 1.7 miles east of, 0.75 mile south of Fountain station, T road north to Clarence, 20 feet north to center of triangle, 40 feet northwest to signpost "Clarence 2 mi.,"	41 01 39.9	77 55 12.3
South Fork of Beech Creek, center of stone arch bridge over,	41 01 25.6	77 54 17.1
Rhoads station, 0.7 mile northwest of, summit of ridge, center of pike,	41 00 56.3	77 53 12.2
Rhoads station, 1,000 feet south of, on east edge Snowshoe-Bellefonte pike, 550 feet north of railroad crossing, in northwest corner of front yard to residence of Joseph Reese; northwest corner of Reese's residence bears S. 69° W., distant 43.4 feet; southwest corner of stone foundation to cellar bears N. 39° 15′ E., distant 71 feet; iron post stamped "Prim. Trav. Sta. No. 8, 1907 PENNSYLVANIA,"	41 00 34.8	77 52 32.2
Rhoads station, 0.25 mile south of, T road east, center of 3 plank bridge,	41 00 27.8	77 52 20.7
Rhoads station, 1 mile southeast of, at bend in main road near old saw mill site, (commonly known as the "Devil's Elbow), second class T road up hill to east, 40 feet southeast to oak, 12 feet northeast to oak, ...	41 00 30.2	77 51 25.0
Devil's Elbow, 0.75 mile southeast of, forks of second class road north, road northwest, 10 feet east to small oak, 70 feet northwest to forked oak,	41 00 01.5	77 50 52.0
Yarnell, 0.5 mile northwest of, forks of road at sawmill northeast and northwest, point of triangle, 20 feet east to oak, 20 feet west to hickory, 35 feet north to sign "Cato 7 mi., Snowshoe 8 mi.,"	41 00 14.3	77 49 00.0
Yarnell, 1 mile northeast of, forks of roads west and south, signpost in center of triangle,	41 00 12.2	77 47 42.7
Fairview Church, 0.25 mile north of, near top of ridge, roads north and northeast, 40 feet north to sign "Yarnell 1.5 mi.," 10 feet east to oak,	41 00 08.3	77 46 57.4

Declination, South border of quadrangle, 5° 59′ West.

BELLEFONTE QUADRANGLES.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Yarnell, 1.25 miles northwest of; on top of ridge, forks of road southeast, second class road to south, 25 feet east to chestnut tree, 15 feet southwest to 2 chestnuts by fence,	40 59 48.0	77 50 07.4

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Yarnell, T road to north at store, center of triangle, 30 feet southeast to corner of blacksmith shop, 25 feet northeast to corner of store (post-office) porch,	40 59 53.5	77 48 43.4
Fairview church and schoolhouse, forks of roads north and east, center of triangle; 30 feet north to sign "Mt. Eagle 4 mi., Marsh Creek 2 mi.," 35 feet southwest to front door of church,	40 59 50.7	77 46 56.0
Fairview church, 1 mile southeast of, forks of road 150 feet south of small log cabin; second class road north, center of 2 plank bridge, 60 feet northwest to forked sycamore, 25 feet east to birch,	40 59 24.4	77 45 54.0
Curtin public schoolhouse, 40 feet west of; at northeast corner of wire fence opposite the junction of the Bald Eagle pike and T road north to Yarnell; northeast corner of schoolhouse bears N. 85° 30′ E. distant 40.6 feet; iron post stamped "Prim. Trav. Sta. No. 9, 1907 PENNSYLVANIA,"	40 58 33.0	77 44 43.7
Curtin schoolhouse, 1 mile southwest of; second class T road north up valley, center of pike,	40 57 54.6	77 45 30.3

GEOGRAPHIC POSITIONS ALONG PENNSYLVANIA RAILROAD MILESBURG VIA BELLEFONTE TO PERU.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Milesburg station, 0.8 mile northeast of, Bellefonte-Lock Haven pike crossing, center of track,	40 57 08.1	77 46 42.0
Milesburg station, 350 feet east of; street crossing, center of main track,	40 56 41.5	77 47 34.4
Highway bridge over Buffalo Run, road crossing, center of main track,	40 55 19.8	77 47 08.8
Bellefonte station, 125 feet north of, High Street crossing, center of main track; 60 feet northwest to corner of Potter, Hay Hardware Company's warehouse, 125 feet south to north end of station,	40 54 42.6	77 46 54.1
Bellefonte station, 1.25 miles southeast of, milepost No. 2,600 feet north of; road crossing, center of track,	04 53 47.7	77 46 20.0
Axeman, 0.5 mile south of, on east edge of Bellefonte-Lewiston pike, in northwest corner of Logans branch public schoolhouse grounds at junction of pike and road southwest to Lemont; iron post stamped "Prim. Trav. Sta. No. 10, 1907 PENNSYLVANIA,"	40 53 08.9	77 45 49.0
Pleasant Gap station, road crossing; center of track,	40 52 18.5	77 45 35.3
Peru (town), T road south to Linden Hall, 30 feet southwest to Beech tree, 10 feet north to wire fence, 30 feet southeast to sign "Linden Hall 4 mi., Lemont 4 mi.,"	40 51 13.0	77 46 05.1

GEOGRAPHIC POSITIONS ALONG HIGHWAYS, PERU TO LINDEN HALL.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Peru, 1 mile south of, second class fork of road to southwest, 10 feet west to old stump, 60 feet south to hickory, ...	40 50 22.7	77 45 43.4
Peru, 1.5 miles south of, forks of road at junction of two valleys, ...	40 49 57.6	77 45 17.6
Old sawmill site, 600 feet southwest of, forks of road, center of bridge over stream, ...	40 49 32.4	77 45 20.2
Linden Hall, 1 mile north of, on side of mountain, 0.5 mile south of summit, forks of roads, roads northeast up mountain, 25 feet west to pine, 30 feet northwest to pine, ...	40 48 48.1	77 46 03.6
Linden Hall, at northwest edge of, 550 feet west of church, T road north to Peru, 40 feet northeast to old log shop, 30 feet northwest to cornerpost of fence, ..	40 47 58.0	77 45 51.5
Linden Hall station, 200 feet east of, road crossing Pennsylvania railroad, center of track, ...	40 47 49.4	77 45 38.8
Linden Hall, 1.25 miles south of, 1.5 miles east of Boalsburg, in center of triangle at T road north; iron post stamped "Prim. Trav. Sta. No. 11, 1907 PENNSYLVANIA,"	40 46 46.2	77 45 34.1

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR SOUTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Boalsburg, east edge of, 250 feet west of bridge over Spring Creek, 3 corners known as Boalsburg Diamond, center of triangle, 20 feet south to sign "Old Fort 8 mi., Tusseyville 5 mi.,"	40 46 33.7	77 47 19.8
Boalsburg, 1 mile west of, 4 corners crossroads; 25 feet southeast to corner of fence, 25 feet northeast to corner of fence, ...	40 46 30.6	77 48 25.7
Shingletown, 0.25 mile east of, T road north, 60 feet east to telephone pole, 15 feet southeast to J. F. Lohr's mailbox, ...	40 46 00.1	77 49 25.7
Shingletown, 1 mile southwest of; fork of roads east and northeast, signpost in center of triangle, sign reads "Pinegrove 3 mi., Lemont 3 mi.,"	40 45 34.3	77 50 40.4
Pinegrove Mills, 2 miles northeast of, 1.5 miles southeast of Bloomsdorf, T road to north, center of triangle, ...	40 44 57.1	77 52 00.5
Bloomsdorf station, 0.5 miles east of, 4 miles south of State College, 6 miles west of Lemont, at corner of garden in northeast corner of intersection of crossroads, iron post stamped "Prim. Trav. Sta. No. 12, 1907 PENNSYLVANIA,"	40 45 35.9	77 52 39.9
Bloomsdorf, 0.5 mile west of, 1.25 miles northwest of Pinegrove, 4 corners crossroads, 20 feet southeast to mailbox at corner of fence, 20 feet southwest to corner of board fence, ...	40 44 57.5	77 53 46.0

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Stone dwellings on north edge of road, 4 corners crossroads, 20 feet northwest to cornerpost of fence, 25 feet northeast to corner of front yard fence, ...	40 44 33.5	77 54 30.1
Stone dwelling, 0.9 mile northwest of, second class T road to west, center of triangle, ...	40 45 13.0	77 55 09.9
Stone dwelling, 1.75 miles northwest of, State College, 4.5 miles southwest of, T road to south, 15 feet south to center of triangle, 50 feet southeast to pine, 10 feet north to fence, ...	40 45 44.5	77 55 30.3
Old sawmill site, forks of roads east and southeast, 120 feet northwest to pump, 60 feet southeast to small pine, ...	40 45 13.2	77 56 46.2

GEOGRAPHIC POSITIONS ALONG SCOTIA BRANCH OF PENNSYLVANIA RAILROAD.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Fairbrook station, 0.5 mile north of, road crossing to field at stub end of siding, center of track, ...	40 44 56.5	77 57 34.9

GEOGRAPHIC POSITIONS ALONG HIGHWAYS.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Gatesburg, 1.75 miles northeast of, 3 corner at railroad junction, center of triangle, 110 feet north to road crossing spur track, 25 feet north to post, 100 feet east to center of railroad, ...	40 45 27.4	77 58 32.1
Gatesburg, 1 mile northeast of, 4 corners, second class crossroads, 80 feet north to farm gate, 50 feet east to leaning oak, ...	40 45 10.5	77 59 23.6

GEOGRAPHIC POSITIONS ALONG HIGHWAYS, GATESBURG NORTH.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Junction, 1 mile northwest of, road crossing spur railroad to mine, center of track, ...	40 46 03.2	77 59 09.2
Summit between Junction and Stormstown, center of road, ...	40 46 49.0	77 59 43.4
Stormstown, 1.5 miles northeast of, 4 corners, cross roads southeast, second class road northwest, 25 feet north to corner of fence, 25 feet west to corner fence,	40 48 37.3	77 59 36.0
Brick Church, 40 feet northeast of, T road to south, east, 30 feet southeast to signpost "Stormstown 3 mi., Scotia 3 mi., State College 7 mi.," 25 feet southwest to corner fence, ...	40 49 12.4	77 58 29.6
Stony Point schoolhouse, 700 feet north of, at south edge of Matternville, T road to north, center of triangle, 40 feet south to signpost "Bellefonte 12 mi., Stormstown 4 mi., Port Matilda 70 mi.," 40 feet west to stone wall, ...	40 49 42.4	77 57 57.6

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Matternville, 0.5 mile northwest of, center of road in gap at summit of Bald Eagle Ridge,	40 50 03.8	77 58 25.4
Martha, 1 mile southeast of, crossroads on side of mountain, 25 feet north to clump of maples, 40 feet northwest to double maple,	40 49 49.5	77 59 25.0

GEOGRAPHIC POSITIONS ALONG TRAILS.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Rattlesnake pike, 1.5 miles southwest of, forks of roads east and northeast, 10 feet north west to pine stump, 40 feet southwest to small leaning pine,	40 54 07.4	77 59 36.9
Rattlesnake Pike, 0.75 mile southwest of, forks of roads southwest and west, tall dead pine tree in angle,	40 54 37.4	77 59 06.9
Rattlesnake Pike, fork to northwest, 150 feet east of T road southeast, 40 feet north to three pronged oak (notched), 60 feet northwest to oak,	40 55 01.1	77 58 38.4
Rattlesnake Pike, 1 mile northwest of, southeast fork of Benner Run, center of old pole bridge over,	40 55 47.9	77 59 29.6

GEOGRAPHIC POSITIONS ALONG PENNSYLVANIA RAILROAD, MILESBURG TO MARTHA.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Snowshoe intersection, center of main track opposite water tank,	40 55 58.1	77 48 52.6
White schoolhouse, 1,000 feet south of, 200 feet east of milepost 28, second class road crossing, center of track,	40 55 22.6	77 50 22.5
Unionville station, 1 mile northeast of, second class road crossing, center of track,	40 54 58.8	77 51 16.3
Unionville, 50 feet east of station, street crossing, center of main track,	40 54 30.8	77 52 13.5
Unionville, 800 feet west of, set in north end of wing wall to east abutment of Pennsylvania Railroad bridge No. 26 over DeWitt River, aluminum tablet stamped "Prim. Trav. Sta. No. 13, 1907 PENNSYLVANIA,"	40 54 18.2	77 52 34.1
Unionville station, 1 mile southwest of, Cline's siding, 150 feet west of, bridge No. 25, 160 feet east of, road crossing, center of track,	40 53 43.0	77 53 30.8
Julian, 1.5 miles northeast of, second class road crossing, center of track,	40 53 04.9	77 54 28.0
Bridge No. 24, 400 feet west of, second class road crossing, 200 feet south of, corner of cemetery, center of track,	40 52 31.9	77 55 28.3
Julian station, 140 feet east of, in south end of wing wall at east abutment to bridge No. 23, over Laurel Run, aluminum tablet stamped "Prim. Trav. Sta. No. 14, 1907 PENNSYLVANIA,"	40 51 54.1	77 56 19.2

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Julian, 0.8 mile west of, 100 feet west of signal tower, road crossing, center of track,	40 51 30.0	77 57 05.1
Bridge No. 21, center of, 50 feet north to T road to north,	40 50 58.4	77 58 12.1
Martha, 1.5 miles northeast of, road crossing, center of track, 40 feet north to 4 corners,	40 50 37.6	77 59 00.0

Declination, west border of quadrangle, 5° 53′ West.
Declination, north border of quadrangle, 5° 59′ West.
Declination, east border of quadrangle, 5° 57′ West.
Declination, south border of quadrangle, 5° 37′ West.
Declination, Center of quadrangle 5° 37′ West.

PENNSYLVANIA.

BUTLER, KITTANNING, SHARPSBURG, SEWICKLEY AND ZELIENOPLE QUADRANGLES, BEAVER, BUTLER AND LAWRENCE COUNTIES.

The following geographic positions were determined by C. B. Kendall, field assistant, by primary traverse in 1906. The line begins with adjusted position at McCaslin and follows highways east to Queens Junction thence along the Allegheny Western Branch of the Bessemer and Lake Erie Railroad to Troutman continuing east along public roads to a point 1 mile west of Karns City, where it turns south via Chicora to the southeast corner of the Butler quadrangle then turns west via Saxonburg, Glade Mills and Callery to Big Knob triangulation station. The circuit was closed on itself by a line beginning at a point about 3 miles east of Callery and running north via Richold and Petersville to Muddy Creek church.

BUTLER QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Elora, at junction of Butler and Mercer pike at road leading west to West Liberty, 25 feet south of southeast corner of the Grange Hall, iron post stamped "Prim. Trav. Sta. No. 2, 1906,"	40 59 13.6	79 59 14.3
Muddy creek church, 5 feet southwest of southwest corner of; center of sandstone boulder,	40 58 22.6	79 58 24.3
Maple Grove schoolhouse, 125 feet south of; forks northwest and southeast, 30 feet south to oak tree and sign, "State Road 2 miles,"	40 58 34.6	79 57 41.3

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Euclid, 1 mile west of; 4 corners at top of hill, 15 feet south to signboard Muddy Creek 2 mi., Euclid 1 mi., Unionville 4 mi., and State road 1 mi.,	40 58 56.2	79 56 55.1
Euclid, 5.0 mile west of; 4 corners at top of hill, 25 feet northwest to corner fence, 30 feet southwest to corner fence,	40 59 10.5	79 56 19.8

GEOGRAPHIC POSITIONS ALONG WESTERN ALLEGHENY BRANCH OF BESSEMER AND LAKE ERIE RAILROAD.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Queen Junction, crossing of the Bessemer and Lake Erie railroad (main line),	40 58 02.6	79 55 53.9
Queen Junction, 1.5 miles east of; public road crossing, center of track,	40 58 34.3	79 54 19.3
Thorn station, 600 feet northeast of; public road crossing, center of track,	40 59 11.8	79 53 13.1
Gilbert station, 0.25 mile west of; in coping at south end of the west abutment of the Western Allegheny railroad girder span over public road 50 feet north of 3 corners, aluminum tablet stamped "Prim. Trav. Sta. No. 3, 1906,"	40 59 40.6	79 51 57.3
Hooker station, 0.75 miles west of; road crossing, public road crossing, center of track,	40 59 46.7	79 50 37.9
Hooker station, 100 feet east of; road crossing, center of track,	40 59 38.0	79 50 00.5
Hooker, 0.75 mile southeast of; overhead crossing, center of track over road,	40 59 06.1	79 49 28.0
Star crossing station, 0.25 mile northwest of; road crossing, center of track,	40 59 30.2	79 48 38.2

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Troutman, 0.5 mile west of and 900 feet east of Western Allegheny railroad, T road to west, center of north and south road, 40 feet southwest to corner wire fence post and signpost Greece 2 mi., Butler 11 mi., 40 feet west to telephone pole,	40 58 54.4	79 48 07.6
Troutman, T road to southeast, 150 feet northeast of store, 40 feet west to corner of blacksmith shop, 20 feet south to corner fence post,	40 59 16.5	79 47 41.0
Troutman, 1.5 miles northeast of; T road up hill to north, 60 feet southwest to oil well, 35 feet southeast to oak tree,	40 59 54.2	79 46 29.1
Hayesville, forks at foot of hill, roads northwest, east and southwest, signpost,	40 59 53.6	79 45 21.2

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR SOUTH BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Saxonburg station, at Saxon Center M. E. Church, T street east, 60 feet north to corner of church, 35 feet southeast to rock foundation to dwelling, ...	40 45 51.8	79 45 57.6
Saxonburg, 1 mile west of station; 4 corners, 15 feet northeast to corner front yard, 35 feet northwest to corner fence, ...	40 45 35.3	79 46 42.5
Saxonburg, 1.2 miles east of; T road north, 250 feet east of T road to south, 25 feet northwest to sign Hannahstown, 1 mi., 20 feet northeast to wire fence post, ...	40 45 34.3	79 47 15.5
Saxonburg, at east edge of; cupola of the German Lutheran church, ...	40 45 00.8	79 48 34.8
Saxonburg, 0.75 mile west of; T road south, center of east and west road, ...	40 45 02.8	79 49 37.1
Saxonburg, 1.8 miles west of; forks 300 feet west of bridge over stream, roads east and north, 30 feet southwest to kitchen door to 2 story dwelling, 30 feet east to large boulder, ...	40 45 01.9	79 50 31.2
Fraziers mill, 600 feet north of; center of bridge over Thorn creek, 500 feet east of Bessemer and Lake Erie railroad, ...	40 45 10.5	79 51 16.6
Saxonburg, 4 miles west of; 1.6 miles west of Fraziers mill, in southeast corner of junction of roads north and south and T road to east, and is 800 feet west of forks south and northeast, iron post stamped "Prim. Trav. Sta. No. 8, 1906,"	40 45 11.2	79 53 04.3
Callery station, 3 miles east of; forks roads southeast and southwest, 25 feet south to sign Glade Mills 5 mi., Brownsdale 2 mi., ...	40 45 02.2	79 59 04 1
Callery station, 3 miles east of; 2 miles south of Brownsdale, in west wall at northwest corner of stone foundation to barn of A. D. Hunter at junction of Glade Mills-Evans City and T road leading southwest to Calery, aluminum tablet stamped "Prim. Trav. Sta. No. 9, 1906,"	40 45 01.1	79 59 03.5
Brownsdale, 0.5 miles southwest of; forks 150 feet southwest of church, roads southwest and west, large oak at, ...	40 46 01.6	79 58 24.9
Brownsdale, 4 corners at top of hill, 50 feet northwest to L. S. Rileys store door, 30 feet west to corner blacksmith shop, ...	40 46 25.6	79 57 59.8
Reibold, 1.5 miles southeast of; 4 corners, 25 feet north to oak, 40 feet northwest to dead oak, 20 feet south to apple tree, ...	40 46 54.8	79 59 18.2
Reibold, 1 mile south of; forks, roads southeast and northeast, center of triangle, ...	40 47 05.7	79 59 48.6
Reibold, 50 feet east of station; road crossing Baltimore and Ohio railroad, center of main track, ...	40 47 53.5	79 59 42.0.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Schoolhouse, 150 feet east of; 4 corners, store in center of intersection of roads, 20 feet northeast to corner of fence and sign Butler road 2 mi., Island road 2 mi., etc., 20 feet southeast to corner fence, ...	40 55 56.6	79 59 54.2
Swamp run, 600 feet north of bridge over, 4 corners, 25 feet southeast to signboard Island road 0.75 mi., Hickory corner 2 mi., 25 feet northwest to sign Unionville 2.25 miles, Franklin road 2.25 miles, ...	40 57 07.5	79 59 57.2
Muddy creek church 1.75 miles southwest of; Junction of Island road and public T road south, forked chestnut tree at junction 120 feet east to forks northeast and southeast, ...	40 57 46.6	79 59 59.2
Muddy creek church, 5 feet southwest of the southwest corner, center of sandstone boulder, ...	40 58 22.60	79 58 24.29

Declination,	north border	W. 4°32′
	south border	W. 3°53′
	east	W. 3 57
	west	W. 4 22

KITTANNING QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR WEST BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Karns City, 1 mile northwest of; 0.75 mile southeast of Hayesville; in southwest angle of junction of Chicora-Fairview and Hayesville-Karns City roads, iron post stamped "Prim. Trav. Sta. No. 4, 1906,"	40 59 44.0	79 44 44.6
Liggett flag station, 150 feet north of W. A. R. R., forks of roads northwest and northeast, center of triangle, ...	40 58 41.9	79 44 50.2
Chicora, at northwest edge of; forks 300 feet north of brick church, roads north and northwest, 80 feet north to telephone pole and sign Fairview 5 mi., 35 feet southwest to telephone pole, ...	40 57 21.0	79 44 54.1
Chicora, in sandstone post in northwest corner of the intersection of Main St., and Central avenue, iron post stamped "Prim. Trav. Sta. No. 5, 1906,"	40 56 57.1	79 44 31.9
Chicora, at southeast edge of; T road south 250 feet southeast of mill, 40 feet southeast to corner of barn, 35 feet north to board fence, ...	40 56 43.0	79 44 14.0
Chicora, 1.3 miles south of; T road to east, center of north and south road, ...	40 55 47.4	79 44 36.9
Chicora, 2.2 miles south of; crossroads 300 feet northeast of schoolhouse, 60 feet southeast to corner of dwellings, 30 feet northeast to post, ...	40 55 04.6	79 44 38.0

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Rattigan, 2 miles west of; 4 corners near top of hill, 10 feet southwest to chestnut tree, 30 feet east to 2 hickory trees,	40 54 23.5	79 44 43.4
Rattigan, 1.9 miles west of; forks of roads southeast and southwest, chestnut tree in triangle,	40 53 42.6	79 44 30.9
St. Joe, 2.5 miles southeast of; 1.25 mile west of Fenelton; in sandstone post 6 by 6 by 36 inches, 24 inches in ground, in center of triangle at junction of Butler-Fenelton and St. Joe-Fenelton roads, and 0.25 mile north of Buffalo, Rochester & Pittsburg railroad, tablet stamped "Prim. Trav. Sta. No. 6, 1906,"	40 52 39.1	79 44 56.0
Coylesville, 1.5 miles west of; center of Butler-Kittanning pike at T road north, 225 feet east of road south, 25 feet north to oak tree,	40 51 28.8	79 44 41.3
Clearfield Catholic church, 4 corners, 15 feet northeast to double oak, 35 feet south to corner of old church,	40 50 37.0	79 44 33.7
Clearfield Catholic church, spire,	40 50 32.3	79 44 35.0
Clearfield Catholic church, 1.1 mile south of; T road to west at brick house, center of north and south road, 40 feet southwest to telephone pole, 70 feet northwest to corner of brick house,	40 49 37.1	79 44 44.5
West Winnfield, 2.8 miles northwest of; forks of roads north and east, 10 feet northwest to 3 mail boxes, 15 feet south to board fence,	40 48 24.9	79 44 49.9
Marwood station, 1.5 mile east of; crossroads at stone house, 100 feet east to signboard Coylesville, 5 miles, Dennys Mill, 2 miles; 20 feet south to oak,	40 47 39.1	79 44 55.3
Saxonburg, 2 miles east of station; 4 corners at Winfield Grange Hall, 25 feet southeast to sign Saxonburg station 2 mi., West Winfield 3 mi., etc., 40 feet southwest to northeast corner of Grange Hall,	40 46 28.0	79 44 54.8
Saxonburg station, 1.5 miles east of; 3 miles west of Liesureville; in sandstone post 6 by 6 by 36 inches 24 inches in ground in southeast corner of intersection of roads, iron post stamped "Prim. Trav. Sta. No. 7, 1906,"	40 45 31.0	79 44 40.2

Declination, west border, 3° 57′ West.

SEWICKLEY QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Callery, 1 mile east of; T road east at store, 300 feet northeast of brick church, center of triangle, 40 feet west to store door, 15 feet south to black locust tree,	40 44 13.0	80 00 37.9

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Callery station, 0.75 mile southeast of; 3 corners at Myoma, T road to east, 50 feet northwest to store door,	40 43 46.6	80 01 34.8
Callery station, 100 feet southwest of; center between main west tracks at street crossing the B. & O. R. R.,	40 44 13.9	80 02 07.3
Callery station, 1 mile northwest of; T road to west, center of north and south road at, 20 feet east to oak, 20 feet west to post painted 1064,	40 44 10.4	80 02 53.5
Callery, 1.5 miles northwest of station; T road to west, 10 feet north to mailbox, 20 feet south to corner wire fence post,	40 44 52.0	80 03 06.2
Callery, 3 miles northwest of station; 4 corners, 15 feet northwest to telephone pole and sign, Callery 3 mi., Evans City 1.5 mi.,	40 44 56.4	80 04 24.7
Forks, roads east and north, 25 feet north to telephone pole, 20 feet southwest to rail fence,	40 44 50.4	80 05 35.2
Three corners, T road to east, 20 feet northeast to locust tree, 30 feet southwest to buggy shed,	40 44 54.9	80 08 25.8
Big Knob triangulation station, 2 miles northeast of; 4 corners, center of north and south road, 10 feet northwest to Adam Teets' mailbox painted 989, 50 feet southeast to dead tree,	40 44 39.4	80 10 45.2
Big Knob triangulation station, 0.75 mile northeast of; forks 100 feet northeast of church, roads west and southwest, 10 feet south to oak, 40 feet east to oak,	40 43 40.5	80 11 13.3
Big Knob triangulation station,	40 43 15.73	80 12 02.87

Declination, north border, 3° 57′ West.

SHARPSBURG QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Forks of public roads north and east, 40 feet east to center of bridge over small stream, 35 feet south to gate and second class road to southeast,	40 44 42.0	79 54 04.8
Two story white house and barn with cupola, 500 feet south of; forks of road northeast and second class road to north, 10 feet east to board fence,	40 43 44.8	79 54 56.9
Glade Mills, junction of plank road and public road to southeast, 20 feet south to northeast corner of old mill, 50 feet northwest to corner of store and post office,	40 43 28.1	79 55 28.4
Glade Mills, 0.5 mile north of; T road northeast at toll gate, 20 feet east to corner of toll house, 40 feet north to corner of yard fence,	40 43 45.8	79 55 24.9
Glade Mills, 1.6 miles northwest of; 4 corners 800 feet east of church, center of triangle; 30 feet southwest to signboard, 40 feet southeast to tree in front yard,	40 44 17.9	79 56 40.6

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
Callery station, 3.0 miles east of; 4 corners near trolley road crossing, 10 feet south to telephone pole and sign Pittsburg 24 miles, 80 feet northwest to sign Brownsdale 2.5 miles, etc., 40 feet east to oak, ...	40 44 28.6	79 58 21.7
Callery, 2.2 miles east of station; forks at top of hill, roads west and southwest, 25 feet northwest to pole gate painted 1145, ...	40 44 28.5	79 59 33.5

Declination, north border, 3° 53′ West.

ZELIENOPLE QUADRANGLE.

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR NORTH BORDER OF QUADRANGLE.

Stations.	Latitude.	Longitude.
	° ′ ″	° ′ ″
McCaslin, 0.8 mile east of; 4 corners, 70 feet north to oak, 20 feet southwest to mailbox painted 1104, ...	41 00 48.9	80 14 39.4
McCaslin, 1.5 miles southwest of; T road north, center of small grass triangle, ...	40 59 57.6	80 14 38.2
Public T road to South, 15 feet southwest to J. A. Book's mailbox, ...	40 59 58.1	80 13 33.5
Slippery Rock creek, 600 feet west of; T road to west, J. M. Curdy's mailbox, ...	41 00 01.0	80 11 19.9
Slippery Rock Creek bridge, 0.25 mile west of; 4 corners near pumping station. 50 feet northeast to a three pronged fir tree, 25 feet southeast to J. E. Forks mailbox, ...	40 59 27.7	80 11 27.1
Grantboro, 4 corners at schoolhouse and store, 40 feet southwest to northeast corner of store, 90 feet east to large oak tree, ...	40 59 17.4	80 10 16.3
Grantboro, 0.9 mile east of; T road east, center of north and south road, 40 feet north to oak tree, ...	40 59 17.3	80 09 16.4
Grantboro, 1.6 miles east of; T road south, center of east and west road, 30 feet southwest to oak tree and sign, Portersfield 5 miles, ...	40 59 18.0	80 08 27.5
Grantsboro, 2.1 miles east of; T road to west, oak tree,	40 59 19.0	80 07 39.8
Jacksville, 1 mile south of; in forks of road, at southwest corner of schoolhouse No. 6, Worth township, Butler county, iron post stamped "Prim. Trav. Sta. No. 1, 1906,"	41 00 09.7	80 07 17.4
West Liberty, 2.5 miles west of; 4 corners 20 feet northwest to signboards, West Liberty 2.5 miles, Rockville 4.5 miles; Prospect 9 miles and Jacksville 1 mile, ...	41 00 27.1	80 05 45.1
West Liberty, 1.6 miles west of; T road north, center of triangle; 20 feet northwest to signboard Slippery Rock 5 miles, ...	41 00 21.2	80 05 01.6
West Liberty, center of bridge over small stream 50 feet east of forks west and southwest, ...	41 00 22.7	80 03 15.9

LIBRARY OF THE UNIVERSITY

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
West Liberty, 0.75 mile southeast of; 4 corners 60 feet southeast to small bridge, 60 feet northwest to oak tree and sign Sunbury, 8 miles; Butler 15 miles, ...	41 00 09.3	80 02 42.5
Vest Liberty, 1.75 miles southeast of; in northwest corner of intersection of crossroads, large oak, ...	40 59 13.0	80 01 23.6
Elora, 0.7 mile west of; T road south, 20 feet south to oak tree and sign "Co. bridge 2 miles,"	40 59 07.4	80 00 01.9

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR SOUTH BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Zelienople, 3 miles southeast of; 3 corner telephone road north and south, T road west, center of triangle, 15 feet southwest to sign Zelienople, 3 miles; 40 feet north to telephone pole, ...	40 45 13.7	80 07 03.4
Schoolhouse, 0.5 mile east of; forks of second class road to south, center of triangle, line between Beaver and Butler counties, ...	40 45 23.2	80 09 12.9
Schoolhouse, 0.5 mile west of Beaver-Butler county line, at T road to east, in east face at southeast corner of stone foundation, aluminum tablet stamped "Prim. Trav. Sta. No. 10, 1906,"	40 45 22.2	80 09 47.6

GEOGRAPHIC POSITIONS ALONG HIGHWAYS NEAR EAST BORDER OF QUADRANGLE.

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Petersville, 0.5 mile south of; 4 corners, 15 feet southeast to signboard, 40 feet southwest to telephone pole, ...	40 48 23.1	80 00 54.1
Petersville, 1 mile north of; T road to south just west of church, 30 feet west to telephone pole and sign Harmony 9 mi., Evans City 6 mi., Franklin road 2 mi.; 15 feet north to corner of wire fence, ...	40 50 02.8	80 00 36.0
Little Connoquenessing creek, center of bridge over, 500 feet south of forks, ...	40 51 06.5	80 00 51.8
Petersville, 4 miles north of; 2 miles east of Whites town, in west wall at southwest corner of stone foundation to Martin schoolhouse No. 2, Conoquenessing to township, aluminum tablet stamped "Prim. Trav. Sta. No. 11, 1906,"	40 52 10.0	80 01 03.2
Schoolhouse, 0.25 mile north of; 4 corners, 20 feet northwest to sign, Oak Spring 2 miles, State road 2 miles; 30 feet northeast to oak, ...	40 52 21.6	80 01 04.4
Mt. Chestnut, about 2 miles west of; T road to E., 25 feet southeast to sign Mt. Chestnut 2 mi.; 15 feet northwest to mailbox, 30 feet northeast to telephone pole, ...	40 53 13.4	80 00 57.2

Stations.	Latitude. ° ′ ″	Longitude. ° ′ ″
Prospect, 1.25 miles east of; T road south, 40 feet west to telephone pole, 25 feet southeast to telephone pole, 400 feet west to T road north,	40 54 18.5	80 00 58.8
Prospect, 2 miles northeast of; 4 corners 40 feet southwest to sign, Prospect 2 mi.; 30 feet east to mailbox,	40 55 04.9	80 01 07.0
Schoolhouse, 0.6 mile south of; 4 corners, 20 feet southeast to oak, 30 feet southwest to corner rail fence,	40 55 23.4	80 00 14.8

APPENDIX C.

RESULTS OF SPIRIT LEVELING IN PENNSYLVANIA FOR THE YEARS 1906-07.

The readjustment in 1903 of the precise-level net in the eastern portion of the United States by the Coast Survey necessitated a corresponding readjustment of all spirit-level heights of the United States Geological Survey dependent thereon.

All results of leveling in Pennsylvania published prior to that time, as well as levels not previously published were then readjusted, rearranged by quadrangles and published in Bulletin 288 of the United States Geological Survey, and also published in the last report of this Commission.

The elevations are arranged according to the degree of accuracy of their determination, precise and primary. The former are determined by lines of levels run either in both forward and backward directions or by simultaneous double-rodded lines, a high-grade instrument being used and special precautions being taken in observations and reductions to correct errors and make the line continuously good throughout. The latter or primary levels are determined with the Y level, precautions being taken against only the principal errors and the levels being run mostly in circuits of single lines. The allowable limit of error observed on the precise work already done by the Geological Survey in this State is represented in feet by $0.03\sqrt{D}$ and that for the primary work by $0.05\sqrt{D}$, in which D is the length of circuit in miles.

The bench marks are of two general forms. First, a circular bronze or aluminum tablet 3½ inches in diameter and one-fourth inch thick, appropriately lettered, having a three-inch stem cemented into a drill-hole, generally in the vertical walls of public buildings, bridge abutments, or other substantial masonry structures. The second form, employed where masonry or rock is not accessible, consists of a hollow wrought iron post 4 feet in length and 3½ inches in outer diameter, split at the bottom and expanded to 12 inches, so as to prevent both the easy subsidence of the post and its being maliciously pulled out of the ground. The iron is heavily coated with asphalt, and over the top of the post is riveted a bronze tablet similar to that described above.

The numbers stamped upon the bench marks represent the elevations to the nearest foot above mean sea level, as determined by unadjusted levels in the field. They have been subjected to changes resulting from the adjustments necessary to close circuits and to those resulting from reduction to mean sea level through readjustment of the precise-level net of the United States. In some cases the finally accepted elevations as printed herein differ from those submitted as bench-mark numbers by 1 or 2 feet. This method of numbering bench marks has been adopted where many levelmen are working in the same area at the same time, as less liable to lead to confusion in identification of bench marks than any attempt at serial numbering, and because the bench mark number at the same time gives an approximate statement of the elevation. It is assumed that engineers and others finding these bench marks so stamped in the field will communicate with the Director of the United States Geological Survey in order to obtain the accepted elevation to hundredths or thousandths of a foot.

Any person finding bench marks mutilated or destroyed will confer a favor by notifying the Director, United States Geological Survey, Washington, D. C.

PENNSYLVANIA.

GETTYSBURG, MIDDLETOWN AND TANEYTOWN QUADRANGLES.

ADAMS, DAUPHIN, LEBANON, LANCASTER AND YORK COUNTIES.

The elevations of bench marks on the Middletown quadrangle are based upon various bench marks of the Pennsylvania Railroad; those on the Gettysburg and Taneytown quadrangle are based upon the elevations of the U. S. Geological Survey bench marks at Idaville and York Springs, which in turn are based upon the bench mark of the Coast and Geodetic Survey precise levels at Carlisle.

The leveling was done in 1906 by J. H. Wetzel, levelman, under the direction of Mr. R. D. Cummin, topographer.

Elevations are based upon the 1903 adjustment and standard bench marks are stamped with figures of elevation.

PENNSYLVANIA.

MIDDLETOWN QUADRANGLE.

MIDDLETOWN VIA WALTONVILLE AND LAWN TO MT. JOY.

	Feet.
Middletown, on railroad bridge, copper bolt, (R. R. B. M.), ...	311.242
Middletown, southeast wing wall stone arch bridge of P. R. R. over Swatara creek, in coping stone, aluminum tablet stamped "311," ..	311.208
Round Top Mill, intersection of roads, in front of M. S. Baum's residence, in large boulder, aluminum tablet stamped "494,"	493.569
Waltonville, in southwest foundation stone of Leander Ridee's barn south of road, aluminum tablet stamped "766,"	766.227
Bachmanville, 3 miles west of; in southeast corner of foundation of Benjamin Coley's residence, aluminum tablet stamped "611,"	611.041
Bachmanville, in southwest corner of Martin B. Brant's brick residence, aluminum tablet stamped "613,"	614.446
Lawn station, in northwest corner of foundation of hotel, aluminum tablet stamped "464,"	464.420
Milton Grove, in southeast corner of foundation of hotel of C. H. Wittie, aluminum tablet stamped "503,"	503.043
Florin, in southeast corner of foundation of Mrs. Metzroth's hotel, primary traverse station No. 3, aluminum tablet stamped "396,"...	395.977
Marietta Street Bridge, at Mt. Joy (R. R. B. M.), ...	360.282

COLUMBIA ALONG PENNSYLVANIA RAILROAD TO HELLAM THENCE ALONG HIGHWAYS TO EMIGSVILLE.

	Feet.
Columbia, under front window of station (R. R. B. M.), ...	252.224
Columbia, 300 feet east of station; on stone door step of Columbia Grocery Co., owned by Miller and Hartman, aluminum tablet stamped "259,"	259.251
West end of south side of track of stone arch bridge No. 8 over 100 feet mill race, aluminum tablet stamped "296,"	296.455
Bridge No. 11, R. R. B. M., ...	326.370
Hellam, corner of Main and National Broadway, in southeast corner of stone foundation of John Goble's stone building, aluminum tablet stamped "385,"	384.724
Mt. Zion, in northwest corner of Mt. Zion Lutheran & Reformed church, aluminum tablet stamped "770,"	770.639
Emigsville, on bridge No. 102, copper bolt, R. R. B. M., ...	375.990

The following tablets were set from bench marks of the Pennsylvania railroad near each place respectively.

Elizabethtown, in third tier of stone from bottom of southwest wing wall of subway at Grafton warehouse, aluminum tablet stamped "457,"	457.376
Conewago Junction station, opposite, in large boulder, aluminum tablet stamped "441,"	441.248
Bainbridge, 120 feet east of station; on north side of track, in ledge of rock in cut, aluminum tablet stamped "273,"	272.709
Falmouth station, in southeast cornerstone of bridge spanning Conewago creek, aluminum tablet stamped "292,"	292.146
Emigsville, 500 feet south of station; in southwest abutment of bridge No. 102, aluminum tablet stamped "375,"	375.285
Mt. Wolf, 420 feet southeast of; in southeast wing wall of stone arch bridge, aluminum tablet stamped "368,"	368.150
Marietta, in northwest corner of porch at entrance to railroad house, aluminum tablet stamped "261,"	260.672

PENNSYLVANIA.

GETTYSBURG AND TANEYTOWN QUADRANGLES ADAMS COUNTY.

GETTYSBURG QUADRANGLE.

IDAVILLE SOUTH ALONG GETTYSBURG AND HARRISBURG RAILROAD TO ROUND TOP.

	Feet.
Bendersville, 0.6 mile south of, in north end of east abutment of concrete arch bridge; aluminum tablet stamped "615,"	614.710
Centerville, 0.7 mile south of, in west end of south abutment concrete railroad bridge; aluminum tablet stamped "577,"	576.955
Biglerville station, in foundation of Reading Dairy Company Building, 500 feet north of station; aluminum tablet stamped "652,"	652.010

	Feet.
Goldenville, 150 feet west of station, in southeast corner of foundation of Milus A. Wilson's residence; aluminum tablet stamped "613,"	613.428
Gettysburg, on large stone at left side of entrance to courthouse; aluminum tablet stamped "553,"	552.969
Round Top station, south side of road at corner of Tipton Park and U. S. Battlefield, in large boulder; aluminum tablet stamped "545,"	544.623

ROUND TOP SOUTHEAST ALONG HIGHWAY TO LITTLESTOWN.

Gettysburg, 5.0 miles southeast of, north side of street at Two Taverns, in southeast corner of stone residence of J. J. Epley; aluminum tablet stamped "510,"	510.314

LITTLESTOWN NORTHEAST ALONG PENNSYLVANIA RAILROAD TO McSHERRYSTOWN THENCE NORTHEAST ALONG WESTERN MARYLAND RAILROAD TO NEW OXFORD THENCE ALONG HIGHWAY TO YORK SPRINGS.

Sells station, in southwest corner of Colvin Good's residence; aluminum tablet stamped "573,"	572.772
McSherrystown, corner Main and Third Sts., at ladies entrance to Union Hotel; aluminum tablet stamped "571,"	571.187
Bettinger, station and post-office; southeast corner of; aluminum tablet stamped "529,"	528.842
New Oxford, corner of Pitts and Boulon Sts., northwest corner of Oxford House; aluminum tablet stamped "560,"	560.092
Hampton, northeast corner of square, in southwest corner of J. P. Myers' brick house; aluminum tablet stamped "550,"	549.389
Round Hill, in northeast corner of J. H. Evans' brick store; aluminum tablet stamped "564,"	563.777

TANEYTOWN QUADRANGLE.

AT LITTLESTOWN.

Littlestown, opposite Catholic Church, on South Queen St., in northwest corner of Huff Hotel; bronze tablet stamped "635,"	634.691

PENNSYLVANIA.

HANOVER AND YORK QUADRANGLES.

YORK COUNTY.

The elevations in the following list are based upon the 1903 adjustment. Leveling of the Pennsylvania railroad furnishes the main control.

The leveling was done in 1907 under Mr. J. H. Wheat, topographer, by Mr. H. D. Hilton.

The work was done in co-operation with the State and the bench marks are stamped with the State name.

HANOVER QUADRANGLE.

BENCH MARKS ALONG NORTHERN CENTRAL BRANCH PENNSYLVANIA RAILROAD.

	Feet.
Brillhart, door step of station, copper bolt R. R. B. M. No. 54, ...	410.96
Brillhart, in northwest doorsill of station; aluminum tablet stamped "411,"	410.893
Glatfelter, 120 feet north of, east center of arch, copper bolt, R. R. B. M. No. 51, ...	439.30
Glatfelter, 225 feet east of railroad crossing, in north west wing wall of bridge over Cordorus creek; aluminum tablet stamped "439,"	438.949
Larue, 150 feet south of, south center coping of arch bridge 78, copper bolt R. R. B. M. No. 46, ...	512.909
Larue, 140 feet east of station, on west side of stone arch bridge on N. C. R. R.; aluminum tablet stamped "513,"	512.823

YORK QUADRANGLE.

BENCH MARKS ALONG NORTHERN CENTRAL BRANCH OF PENNSYLVANIA RAILROAD.

Milepost 59, 2,100 feet north of, southwest wing wall of bridge 98, R. R. B. M. No. 62, copper bolt, ...	372.77
Milepost 59, 2,100 feet north of, in southeast abutment of bridge 98, aluminum tablet stamped "372,"	372.404
York, doorstep of baggage room, R. R. B. M. No. 60, copper bolt, ..	371.40
York, 100 feet west of Western Maryland station, on southwest abutment of wagon bridge over Codorus creek; aluminum tablet stamped "368,"	367.683
Glen Rock, south of, R. R. B. M. 43, 180 feet south of milepost 42, northwest back wall of bridge 74; copper bolt, ...	548.140
Glen Rock, 180 feet south of milepost 42, northeast wing wall of bridge No. 74; aluminum tablet stamped "548,"	547.764
Shrewsbury, on station step, R. R. B. M. 40, copper bolt, ...	737.840
Shrewsbury, Traction Hotel, northwest corner of, 35 feet east of railroad; aluminum tablet stamped "741,"	741.088

BENCH MARKS ALONG YORK BRANCH PENNSYLVANIA RAILROAD.

Heistand, overhead bridge, south side, projecting bolt, R. R. B. M. No. 9, ...	441.26
Heistand, northwest pier of overhead bridge, 0.6 foot from ground; aluminum tablet stamped "436,"	436.346
Hellam, 1,250 feet west of station, northwest abutment bridge 14, R. R. B. M.; copper bolt, ...	354.62
Hellam, 1,250 feet west of station, on northeast abutment of bridge 14; aluminum tablet stamped "354,"	354.307

STONER SOUTH TO YORKANA. (SINGLE SPUR LINE.)

Milepost 5, 1,125.7 feet west of, in southeast abutment of bridge 12, R. R. B. M. No. 12; copper bolt, ...	326.370

	Feet.
Yorkana, east end of at crossroads, road running north to Hellam station, in stone at entrance to residence to Wilton Myers, northeast corner of crossroads; aluminum tablet stamped "648,"	648.098

STONER ALONG HIGHWAY SOUTHEAST TO EAST PROSPECT THENCE SOUTH TO BITTERVILLE THENCE SOUTHWEST TO GLEN ROCK.

East Prospect, north end of, in east end of foundation of schoolhouse; aluminum tablet stamped "493,"	493.286
Bittersville, in northeast foundation of United Evangelical Church; aluminum tablet stamped "567,"	566.851
Red Lion, in front of station; top of east rail, ...	897.8
Red Lion, 125 feet south of railroad, in stone step of Myers building, southwest corner of; aluminum tablet stamped "911,"	910.800
Dallastown, on summit of hill at cross streets, top of rail, ...	928.0
Rye, in southwest foundation of house of C. A. Hess at crossroads; aluminum tablet stamped "733,"	732.984
Loganville, in southwest corner of foundation of P. O.; aluminum tablet stamped "782,"	782.306

SHREWSBURY ALONG HIGHWAY EAST TO STEWARTSTOWN THENCE NORTHEAST TO DOLF THENCE NORTH TO BITTERSVILLE.

Sheffer, at road crossing near; top of west rail, ...	794.09
Tolna post office, in stone step of post office north side of railroad; aluminum tablet stamped "774,"	774.178
Orwig, in front of station; top of north rail, ...	865.4
Stewartstown station, top of south rail, ...	844.1
Stewartstown, in stone step at entrance to Methodist Episcopal Church on Main St. and College Ave.; aluminum tablet stamped "886,"	885.571
Dolf, in southeast corner of foundation of barn owned by John A. Wilson, aluminum tablet stamped "775,"	774.592
Parke, post-office, 1.5 miles west of, in northwest corner of foundation of Glessic schoolhouse at crossroads; aluminum tablet stamped "755,"	754.002
Keys, 100 feet east of post-office, in northwest foundation of barn owned by G. B. Murphy; aluminum tablet stamped "839,"	839.244

PENNSYLVANIA.

BEDFORD AND WINDBER QUADRANGLES.

BEDFORD AND SOMERSET COUNTIES.

The elevations in the following list are based upon the 1903 adjustment. Leveling of the Pennsylvania railroad furnishes the initial control.

The leveling was done partly in 1901 under Mr. A. M. Walker, topographer, by J. B. McGuire, levelman, and in 1907 under Mr. J. H. Wheat, topographer, by Mr. H. D. Hilton, levelman.

The work was done in co-operation with the State and the standard bench marks are stamped with the State name.

BEDFORD QUADRANGLE.

BENCH MARKS ALONG PENNSYLVANIA RAILROAD BEDFORD TO MANN'S CHOICE.

	Feet.
R. R. B. M. No. 20, Bedford, capstone of pier, southeast corner of freight station, chiseled square,	1,060.150
Bedford, in northwest abutment of wagon bridge over river 250 feet south of railroad; aluminum tablet stamped "1064,"	1,064.002
Wolfsburg, 500 feet south of station, east end of box culvert; R. R. B. M. No. 18; copper bolt,	1,096.92
Wolfsburg, west end of, in northwest foundation of schoolhouse; aluminum tablet stamped "1122,"	1,122.133
Napier Station, 0.7 mile from, on rock, copper bolt, R. R. B. M. No. 17,	1,095.63
Napier, 350 feet north of station, northeast abutment of bridge No. 7; aluminum tablet stamped "1106,"	1,104.815
Napier, in front of station; top of rail,	1,108.9
Mount Dallas, 14.3 miles from, north abutment, east end of coping, copper bolt, R. R. B. M. No. 16,	1,116.73
Mann Choice, R. R. B. M. 15, north abutment of open culvert, copper bolt,	1,135.68
Manns Choice, 690 feet south of station, in southeast corner of foundation of grist mill; aluminum tablet stamped "1136,"	1,135.832

ELTON SOUTHEAST TO LOVELY THENCE NORTH TO PAVIA.

Felix, 3.3 miles north of, 600 feet east of Felix road, in large rock on north side of Barefoot road; aluminum tablet stamped "2840,"	2,839.728
Elton, 10.1 miles east of, 535 feet west of intersection of Old Johnstown road with road to Lovely, on north side of Barefoot road, on rock; aluminum tablet stamped "2015,"	2,014.737
Lovely, in northwest corner of stone wall of building used as post-office at southeast corner of crossroads; bronze tablet stamped "1314 PITTSBURG,"	1,312.901

BEDFORD NORTH ALONG HIGHWAY TO WEYANT THENCE WEST TO LOVELY.

Belden, northeast corner of crossroads, in large round stone at entrance to store; aluminum tablet stamped "1083,"	1,083.013
Cessna, road crossing at station; top of rail,	1,079.6
Cessna, 930 feet west of station, on northeast abutment of bridge over Dunning Creek; aluminum tablet stamped "1077,"	1,076.931
Fishertown, in front of station; top of rail,	1,089.6

	Feet.
Reynoldsdale, in northwest corner of foundation of post office 100 feet south of railroad station, on east side of track; aluminum tablet stamped "1105,"	1,104.922
Osterburg station, 4,500 feet west of, in foundation of covered bridge over Bobbs creek, on northwest side of bridge, 6 feet from water; aluminum tablet stamped "1144,"	1,143.892
Weyant, in northwest foundation of building used as post office; aluminum tablet stamped "1256,"	1,256.351

MANNS CHOICE WEST ALONG HIGHWAY TO COUNTY LINE.

Schellsburg, in building used as post office at crossroads, northeast corner of step; aluminum tablet stamped "1259,"	1,258.772
Fyan, in foundation of mill, in southeast corner of, 500 feet north of Pittsburg and Baltimore pike; aluminum tablet stamped "1399,"	1,399.031

FROM COUNTY LINE 4 MILES WEST OF FYAN NORTHEAST ALONG HIGHWAY TO B. M. 4 MILES NORTH OF FELIX.

Daley, in step of building used as store, northeast corner of crossroads; aluminum tablet stamped "2617,"	2,616.723
Daley, 3.3 miles north of, at old log house in field and small buildings along road, east side of road, in large rock; aluminum tablet stamped "2560,"	2,560.247
Crumb, 1.1 mile north of, 240 feet north of intersection opposite spruce tree, west side of road, in large stone; aluminum tablet stamped "2507,"	2,506.637
Felix, in foundation of building used as post office, in southeast corner of; aluminum tablet stamped "2326,"	2,325.571

WINDBER QUADRANGLE.

AT CROSSROADS 4 MILES WEST OF FYAN.

Fyan, 4 miles west of, at northeast corner of crossroads, on Allegheny Mountain, in large rock; aluminum tablet stamped "2594,"..	2,593.468

PENNSYLVANIA.

BROOKVILLE AND SMICKSBURG QUADRANGLE.

ARMSTRONG, CLARION, INDIANA AND JEFFERSON COUNTIES.

The elevations in the following list are partly recopied from Bulletin 288, pages 35 and 39, based upon the 1903 adjustment of precise leveling. The republished work on Smicksburg quadrangle was done in 1902 under Mr. Frank Sutton, geographer, by Mr. Ira N. Flocker, levelman, and the new work in 1906-7 under Mr. Robert D. Cummin and Mr. W. O. Tufts, topographers, respectively by Messrs. J. H. Wetzel and H. D. Hilton respectively. The republished work on Brookville quadrangle was done in 1905 under Mr. W. T. Griswold, topographer, by Mr. B. J. Green, levelman, and the new work was done in 1907 under Mr. Tufts by Mr. Hilton.

SMICKSBURG QUADRANGLE.

VALIER, ALONG PENNSYLVANIA AND NORTHWESTERN RAILROAD, TO DAYTON.

	Feet.
Valier, road crossing; top of rail,	1,225
Hamilton, road crossing, top of rail,	1,190
Hamilton, 60 feet west of, 5 feet south of track, in top of large rock, aluminum tablet stamped "1188 PITTSBURG,"	1,187.015
Loop, 0.25 mile west of, high bridge over Mahoning Creek, in south end of east abutment; aluminum tablet stamped "1183 PITTS.,"...	1,182.458
Goodville, crossing at station; top of rail,	1,215
Dayton, 900 feet west of station, northwest wing wall of Buffalo, Rochester and Pittsburg Railroad bridge over small stream, on second coping stone; aluminum tablet stamped "1326 PITTSBURG,"	1,326.118

DAYTON SOUTHEAST ALONG HIGHWAYS TO MARION CENTER THEN SOUTH ALONG THE BUFFALO, ROCHESTER AND PITTSBURG RAILROAD TO HOME STATION THENCE BY HIGHWAYS TO GAIBLETON.

Dayton, 3 miles south of, 500 feet south of crossroads, in foundation of W. R. Spur house, at end of east side of; aluminum tablet stamped "1365 ADJ 1903,"	1,365.408
Barnards, 2 miles south of, in southeast corner of foundation of Dunkards church; aluminum tablet stamped "1219 ADJ 1903,"	1,220.292
Plumville, at schoolhouse, in northeast wing wall of iron wagon bridge; aluminum tablet stamped "1168 ADJ 1903,"	1,169.359
Ambrose, in northeast corner of foundation of D. R. Lewis' store building; aluminum tablet stamped "1161 ADJ 1903,"	1,162.566
Marion Center, 960 feet north of station, on east side of southeast abutment of bridge over stream; aluminum tablet stamped "1259 ADJ 1903,"	1,260.190
Marion Center, in front of station; top of rail,	1,259.0
Home station, in front of; top of rail,	1,197.2

HAMILTON SOUTH ALONG HIGHWAYS TO MARION CENTER. (ONE FOOT ADJUSTMENT IS THROWN AT END OF THIS LINE.)

Cavode, in west foundation wall of Neff & Warushuis store building; aluminum tablet stamped "1531 ADJ 1903,"	1,531.159
Hamil, in southwest wing wall of iron bridge spanning Little Mahoning Creek; aluminum tablet stamped "1225 ADJ 1903,"	1,225.599
Hamil, road crossing at station; top of west rail,	1,250

HAMILTON NORTHWEST ALONG HIGHWAYS TO SPRANKLES MILLS.

Grange, 400 feet north of post office, in east side of southeast corner of barn foundation owned by L. V. Means; aluminum tablet stamped "1713 ADJ,"	1,712.883

BROOKVILLE QUADRANGLE.

HOLDEN, SOUTHEAST ALONG PITTSBURG, SUMMERVILLE AND CLARION RAILROAD, TO SUMMERVILLE THENCE SOUTHWEST ALONG PENNSYLVANIA RAILROAD (LOW GRADE DIVISION) TO MAYPORT. (MEAN OF TWO LINES.)

	Feet.
Holden, 1.2 miles southeast of, on east end of south abutment of small bridge just south of private crossing (county road 75 feet east of); aluminum tablet stamped "1433 ADJ 1903,"	1,432.333
Summerville, on northwest corner of railroad bridge over Redbank Creek; aluminum tablet stamped "1160 ADJ 1903,"	1,159.890
Heathville, in coping at west end of north abutment of bridge No. 51, over Beaver Run; aluminum tablet stamped "1158 ADJ 1903,"	1,157.456
Heathville, 0.7 mile southwest of, in coping at northwest corner of north abutment of bridge No. 52 over Redbank Creek; railroad bench mark 1,154.69,	1,153.994
Pattons Station post office, in north pier of water tank; copper bolt stamped "1137.255,"	1,136.554
Mayport, (New Mayville post office), 1 mile east of, in north coping of stone arch bridge over run and road; aluminum tablet stamped "1108 ADJ 1903,"	1,106.892

SPRANKLES MILLS NORTHWEST ALONG HIGHWAYS TO PATTONS STATION.

Sprankles Mills, west end of, in foundation of house owned by Wm. Eisenhart Estate, opposite to store, in east side of at southeast corner; aluminum tablet stamped "1271 ADJ 1903,"	1,271.334
Worthville, northwest end of, in second step of S. W. Geist store, west side of southwest corner; aluminum tablet stamped "1193 ADJ 1903,"	1,192.681
Langville, 100 feet west of, 5 feet west of T roads, in top of large rock; aluminum tablet stamped "1200 ADJ 1903,"	1,199.594

PENNSYLVANIA.

FOXBURG QUADRANGLE.

ARMSTRONG, BUTLER AND CLARION COUNTIES.

The elevations in the following lists are based upon a precise level line of the U. S. Geological Survey Franklin to Pittsburg and the 1903 adjustment.

Elevations along the precise line on this quadrangle are found in the U. S. Geological Survey, Bulletin No. 288, pages 12 and 13.

The leveling on the north half of this quadrangle was done in 1905 under the direction of Mr. W. T. Griswold, topographer, by Mr. B. J. Green, levelman. All standard bench marks are stamped "ADJ 1903" in addition to the figures of elevation. That of the south half was done in 1906 under the direction of Mr. R. D. Cummin, topographer, by Mr. J. H. Wetzel, levelman; all standard bench marks are stamped with the figures of elevation to the nearest foot.

FOXBURG QUADRANGLE.

PARKER, NORTHEAST ALONG BALTIMORE AND OHIO RAILROAD (NARROW GAUGE), TO SHIPPENVILLE.

	Feet.
Foxburg, in stone door sill of baggage room at Pennsylvania station; copper,	892.544
Roxburg, in east wall near entrance to "The Inn," opposite station; aluminum tablet stamped "885 ADJ 1903,"	884.494
Richmond, (Alum Rock P. O.), opposite, in door step of hotel building; bronze tablet stamped "1190 ADJ 1903,"	1,190.389
Blairs Corners, 1,000 feet east of; bridge over Beaver Run, north end of west abutment, by flouring mill; bronze tablet stamped "1157 ADJ 1903,"	1,156.826
Knox, at southeast corner of Main and State streets, in foundation wall at northeast corner of B. A. Kribbs & Co.'s brick building; aluminum tablet stamped "1382 ADJ 1903,"	1,381.839

PARKERS LANDING NORTHEAST TO CALLENSBURG THENCE SOUTHEAST VIA TOBY TO CHERRY RUN.

Freedom, wagon bridge at south end of; southeast wing wall of; aluminum tablet stamped "1262,"	1,262.005
Callensburg, 0.5 mile southwest of; in southeast corner of Prospect schoolhouse foundation, aluminum tablet stamped "1069,"	1,068.685
Toby, post office, iron wagon bridge spanning Cherry Run, in northwest bridge seat; aluminum tablet stamped "1147,"	1,146.724
Cherry Run (Hurley P. O.), in store building and station; bronze tablet stamped "1241,"	1,240.605

PARKERS LANDING SOUTHWEST VIA BRUIN TO PETROLIA THENCE EAST TO FREDERICKSBURG THENCE NORTH TO WEST MONTEREY.

Stonehouse station, 500 feet northeast of; east side of track, in large boulder, aluminum tablet stamped "1055,"	1,055.388
Bruin, in southeast wing wall of iron wagon bridge over Little Bear Creek, aluminum tablet stamped "1092,"	1,091.846
Petrolia, southwest corner of foundation of residence of Mrs. Mary Duffy, aluminum tablet stamped "1264,"	1,263.723
Fredericksburg, in northeast corner of stone foundation of Mrs. Margaret Shakeley's residence, aluminum tablet stamped "1299,"	1,299.092

PENNSYLVANIA.

BUTLER, NEW CASTLE AND ZELIENOPLE QUADRANGLES.

BEAVER, BUTLER AND LAWRENCE COUNTIES.

The elevations in the following list are based upon the 1907 adjustment of precise leveling.

The descriptions of bench marks on New Castle quadrangle are recopied from Bulletin 288, page 49, with corrected elevations; the work on Butler and Zelienople quadrangles are based upon bench marks at Bartley, Chicora and Downieville, described in same bulletin, pages 40 and 46. The bulletin elevations for Bartley and Downieville were decreased 0.2 foot to agree with 1907 adjustment of the B. & O. precise level line. No B. & O. bench marks were found on Zelienople quadrangle and on account of nearly 1 foot error in circuit Harmony via Frisco and Prospect a connection should be made in 1908 from Frisco west to some B. & O. bench mark.

The leveling on New Castle quadrangle was done in 1901 under Mr. Frank Sutton, geographer, by Mr. Ira M. Flocker, levelman, except at Frisco. The leveling at Frisco and on Butler and Zeilenople quadrangles was done in 1907 under W. O. Tufts, topographer, by Mr. C. B. Burns, levelman.

BUTLER QUADRANGLE.

BARTLEY NORTH ALONG PITTSBURG, BESSEMER AND LAKE ERIE RAILROAD TO BUTLER THENCE NORTHEAST ALONG BALTIMORE AND OHIO RAILROAD TO CHICORA.

	Feet.
West Saxonburg, in front of station; top of rail,	1,140.2
West Saxonburg, 0.17 mile north of, west side of railroad, 40 feet center of track, in sandstone outcrop; aluminum tablet stamped "1145 ADJ 1903,"	1,144.612
Rockdale, in sandstone abutment of bridge over county road; aluminum tablet stamped "1056 ADJ 1903,"	1,056.263
McBride, road crossing; top of rail,	952
McBride, 0.57 miles north of, 60 feet from center of track, on west side of railroad, in sandstone wing wall of county bridge; aluminum tablet stamped "985 ADJ 1903,"	984.987
Odel, on east side of railroad, in sandstone outcrop; aluminum tablet stamped "1016 ADJ 1903,"	1,015.851
Butler, Butler County National Bank, at entrance at northeast corner of building, in sandstone pillar; aluminum tablet stamped "1077 ADJ 1903,"	1,077.080
East Butler, 0.21 mile north of; 60 feet west of Baltimore and Ohio railroad, in sandstone abutment of plat girder bridge of Buffalo, Rochester and Pittsburg railroad; aluminum tablet stamped "1028 ADJ 1903,"	1,028.025

	Feet.
Carbon Center, 1.26 miles north of, northwest corner of railroad bridge, in sandstone abutment; aluminum tablet stamped "1123 ADJ 1903,"	1,122.461
North Oakland, road crossing; top of rail,	1,326

BUTLER SOUTHEAST ALONG PENNSYLVANIA R. R. TO BRINKER STATION.

Brinker, road crossing at station; top of rail,	1,232.0
Brinker station, 300 feet east of station, south side of road, in sandstone culvert; aluminum tablet stamped "1232 ADJ 1903,"	1,231.949

BUTLER NORTHWEST ALONG PITTSBURG, BESSEMER AND LAKE ERIE RAILROAD TO QUEEN JUNCTION.

Butler, 3.48 miles north of, in concrete abutment of railroad bridge, southeast corner of bridge; aluminum tablet stamped "1021 ADJ 1903,"	1,021.302
Oneida, road crossing; top of rail;	1,030
Oneida, 1.9 miles north of, in northeast corner of railroad bridge abutment; aluminum tablet stamped "1110 ADJ 1903,"	1,109.409
Jamisonville, in front of station; top of rail,	1,169.2
Queen Junction, at junction of Bessemer and Western Allegheny railroads, in concrete bridge abutment railroad bridge; aluminum tablet stamped "1226 ADJ 1903,"	1,225.945

ZELIENOPLE QUADRANGLE.

DOWNIEVILLE NORTHWEST ALONG BALTIMORE AND OHIO RAILROAD TO FRISCO.

(B. & O. bench marks were destroyed on this route and a connection should be obtained in 1908 with Ellwood City B. Ms. of B. & O. R. R.)

Callery Junction, street crossing; top of rail,	974.8
Calery Junction, 0.75 mile west of, north side of railroad, in concrete abutment of trolley bridge; aluminum tablet stamped "988 ADJ 1903,"	988.061
Evans City, 70 feet east of station, north side of railroad, in sandstone abutment of county bridge; aluminum tablet stamped "939 ADJ 1903,"	939.159
Harmony, in sandstone door stoop to High School building; aluminum tablet stamped "925 ADJ 1903,"	925.444
Zelienople, at road crossing; top of rail,	908
Old Furnace, 0.39 mile west of, southeast corner of railroad bridge, in sandstone abutment; aluminum tablet stamped "896 ADJ 1903,"	895.694
Fombell, road crossing,	886
Gohering, road crossing; top of rail,	875
Celia, northwest corner of bridge, in concrete mud wall; aluminum tablet stamped "875 ADJ 1903,"	874.831
Hazen, road crossing; top of rail,	869
McKimms, road crossing; top of rail,	866
North Sweekley, in front; top of rail,	885

HARMONY NORTH ALONG HIGHWAYS TO ISLE THENCE EAST ALONG RAILROAD TO QUEEN JUNCTION.

	Feet.
Whitestown, 5.47 miles south of, in sandstone wing wall of county bridge, northwest end of bridge; aluminum tablet stamped "938 ADJ 1903,"	938.147
Whitestown, 1.71 miles south of, at sharp bend, 30 feet center of road, west side of road, in stone outcrop; aluminum tablet stamped "1206 ADJ 1903,"	1,206.479
Prospect, in sandstone door stoop to public school building; aluminum tablet stamped "1369 ADJ 1903,"	1,369.148
Isle, in foundation of private house owned by E. A. Watson, stone foundation; aluminum tablet stamped "1189 ADJ 1903,"	1,189.129

FRISCO NORTHEAST ALONG HIGHWAYS TO PROSPECT.

ONE FOOT ADJUSTMENT THROWN AT BEGINNING OF THIS LINE.

Wortemburg, north end of, at county bridge over Slippery Creek, in sandstone abutment; aluminum tablet stamped "851 ADJ 1903,"	850.231
Wortemburg, 3.20 miles north of, 100 feet from center of road, on west side of road, in sandstone foundation of large barn; aluminum tablet stamped "1278 ADJ 1903,"	1,277.486
Wortemburg, 5.6 miles north of, 50 feet west of road at road fork on east, in sandstone foundation at private house; aluminum tablet stamped "1321 ADJ 1903,"	1,320.452
Portersville, in front of Kennedy Hotel, in large round sandstone; aluminum tablet stamped "1381 ADJ 1903,"	1,380.550
Portersville, 2.83 miles east of, road fork on north, in front of Oak Grove schoolhouse, in sandstone boulder; aluminum tablet stamped "1403 ADJ 1903,"	1,402.449

PORTERSVILLE ALONG HIGHWAYS TO POINT 2.8 MILES NORTHWEST OF PORTERSVILLE AND RETURN.

Portersville, 2.83 miles northwest of, on east side of road; in sandstone boulder; aluminum tablet stamped "1191 ADJ 1903,"	1,190.324

NEW CASTLE QUADRANGLE.

AT FRISCO.

Frisco, 0.25 mile west of, in northeast corner of railroad bridge, in sandstone mud wall at east end of tunnel; aluminum tablet stamped "894 ADJ 1903,"	893.726
Frisco, at road crossing; top of rail,	892

NEW GALILEE, SOUTHWEST ALONG RAILROAD TO DARLINGTON AND RETURN.

New Galilee, northeast corner of east back wall of bridge No. 42, bench mark No. 2116 (Pittsburg, Fort Wayne and Chicago railroad precise levels),	959.265

	Feet.
New Galilee, 1 mile southwest of, Pittsburg, Lisbon and Western R. R. bridge over Little Beaver, northeast corner of south abutment,	930.925
Darlington, at intersection of Market and Second streets, in front of Darlington Hotel, on top of stone, bronze tablet stamped "912.5 PITTSBURG 1901,"	911.777

AT BEAVER FALLS.

Beaver Falls, bench mark 1596 (Pittsburg, Fort Wayne and Chicago R. R. precise levels),	789.374
Beaver Falls, Pittsburg, Fort Wayne and Chicago R. R. bridge over Eleventh street, west end of south abutment, in coping stone; aluminum tablet stamped "789.8 PITTSBURG 1901,"	789.485

ENON NORTH ALONG HIGHWAY VIA MOUNT JACKSON TO NEWCASTLE THENCE SOUTHEAST ALONG PITTSBURG AND LAKE ERIE RAILROAD VIA WAMPUM TO HOMEWOOD.

Enon, bench mark 2385, Pittsburg, Fort Wayne and Chicago R. R. precise levels,	995.149
Enon, 400 feet south of railroad tracks on Main St., in top of county line stone; bronze tablet stamped "1013.4 PITTSBURG 1901,"	1,012.701
Mount Jackson, at post office, 60 feet north of street intersection, in side of square stone hitching post; bronze tablet stamped "1165 PITTSBURG,"	1,164.301
Mahoningtown, highway bridge over the Mahoning, on wing wall of south abutment (nearest Pittsburg, Youngstown and Ashtabula R. R. track); seat cut in corner of,	785.527
Mahoningtown, in front of station, Pittsburg, Lake Erie southbound track; north rail,	779.1
Newcastle, in front of station; top of rail,	806
Wampum, in front of station; top of rail,	802.8
Wampum, 500 feet south of station, northeast corner of arch bridge over Wampum Run, on coping stone; aluminum tablet stamped "804.7 PITTSBURG,"	804.200
Homewood, bench mark 1840, (Pittsburg, Fort Wayne and Chicago R. R. precise levels),	949.950

APPENDIX D.

LIST OF COMPLETED TOPOGRAPHIC MAPS.

The annexed table represents the completed surveys. Of these 112 are published, and can be had from the United States Geological Survey, and the others are in course of publication and will soon be issued.

There is also some incompleted topographic work from last year, which will be completed, and some work completed in the way of "overrun," in skeching in the details along the lines of the quadrangles.

Quadrangle.	Area mapped.
Accident (Md.-Pa.-W. V.),	25.86
Allentown,	226.73
Amity,	228.40
Andover (Pa.-Ohio),	17.60
Barnesboro,	226.73
Beaver,	226.73
Belair (W. Va.-Md.),	26.00
Blacksville (W. Va.-Pa.),	26.28
Bloomsburg,	225.06
Bordentown (N. J.-Pa.),	2.82
Boyertown,	227.57
Brownsville,	228.40
Bruceton (W. Va.-Pa.),	26.61
Burgettstown,	227.57
Burlington (Pa.-N. J.),	138.59
Camden (N. J.-Pa.-Del),*	209.73
Cameron (W. Va.-Ohio-Pa.),	17.60
Carlisle,	228.40
Carnegie,	227.57
Catawissa,	225.90
Chambersburg,	229.22
Chester (Pa.-Del.-N. J.)†	153.73
Clarion,	225.06
Claysville,	228.40
Coatesville,	229.22
Conneaut,	16.00
Connellsville,	228.40

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*Chester and Philadelphia sheets, on scale of 1:62,500, have been reduced, and form parts of Camden sheet, on scale of 1:125,000.

†Philadelphia and vicinity sheet includes Chester, Germantown, Norristown and Philadelphia sheets.

Quadrangle.	Area mapped.
Curwensville,	225.90
Delaware Water Gap (Pa.-N. J.),	131.01
Doylestown (Pa.-N. J.),	207.10
Dundaff,	223.36
Easton (Pa.-N. J.),	80.18
Ebensburg,	227.57
Elders Ridge,	226.73
Elkland,	222.50
Elkton (Md.-Del.-Pa.),	28.50
Elmira (N. Y.-Pa.),	1.55
Erie,	114.61
Everett,	228.40
Fairview,	22.92
Flintstone (Md.-Pa.-W. Va.),	26.91
Frostburg (Md.-W. Va.,-Pa.),	26.37
Gaines,	222.50
Germantown (Pa.-N. J.),†	225.00
Gettysburg,	229.22
Girard,	219.50
Grantsville (Md.-Pa.),	25.86
Greensburg,	227.57
Hancock (W. Va.-Md.-Pa.),	25.37
Harrisburg,	227.57
Harvey Lake,	224.21
Havre de Grace (Md.-Pa.),	25.36
Hazleton,	225.90
Hollidaysburg,	227.57
Honesdale,	233.36
Honeybrook (Suplee),	227.40
Houtzdale,	225.90
Hummelstown,	227.57
Huntingdon,	227.57
Indiana,	226.73
Johnstown,	227.57
Kinsman,	17.60
Kittanning,	225.90
Lambertville (Pa.-N. J.),	49.86
Lancaster,	228.40
Latrobe,	227.57
Lebanon,	227.57
Littleton (W. Va.-Pa.),	1.95
Lykens,	228.73
Mahanoy,	225.90
Mannington (W. Va.-Pa.),	26.28
Masontown,	229.22
Mercersburg,	229.22
Millersburg,	226.73
Millerstown,	226.73
Morgantown (W. Va.-Pa.),	26.53
Newcastle,	225.90
Neshannock,	225.06

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†Philadelphia and vicinity sheet includes Chester, Germantown, Norristown and Philadelphia sheets.

Quadrangle.	Area mapped.
New Bloomfield,	227.57
New Cumberland,	228.40
New Holland,	228.40
Norristown,†	228.40
Owego (N. Y.-Pa.),	1.29
Parkton (Md.-Pa.),	26.00
Patton,	226.73
Pawpaw (Md.-W. Va.-Pa.),	25.86
Philadelphia (Pa.-N. J.),*	56.00
Philadelphia and vicinity (Pa.-N. J.-Del.),†	623.13
Phoenixville,	228.40
Pinegrove,	226.73
Pittsburg,	227.57
Pittston,	224.21
Port Jervis,	6.00
Pottsville,	226.73
Punxsutawney,	225.90
Quakertown,	227.57
Reading,	227.57
Rogersville,	229.22
Rural Valley,	225.90
Scranton,	224.21
Sewickley,	226.75
Shamokin,	225.90
Shickshinny,	225.06
Slatington,	226.73
Steubenville (Ohio-W. Va.-Pa.),	17.60
Sunbury,	225.90
Tioga,	225.50
Uniontown,	229.22
Wallpack (N. J.-Pa.),	52.50
Waynesburg,	229.22
Wellsville (Ohio-W. Va.-Pa.),	17.60
Wernersville,	227.57
West Chester (Pa.-Del.),	165.55
Westminster (Md.-Pa.),	26.00
Wheeling (W. Va.-Ohio-Pa.),	17.60
Wilkes-Barre,	225.06
York,	229.22
York special,	75.33
Youngstown,	17.60

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*Chester and Philadelphia sheets, on scale of 1:62,500, have been reduced, and form parts of Camden sheet, on scale of 1:125,000.

†Philadelphia and vicinity sheet includes Chester, Germantown, Norristown and Philadelphia sheets.

APPENDIX E.

REPORT OF PROGRESS OF CO-OPERATIVE GEOLOGICAL SURVEY.

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REPORT OF PROGRESS ON GEOLOGIC WORK

UNDER THE

TOPOGRAPHIC AND GEOLOGIC SURVEY COMMISSION OF PENNSYLVANIA,

IN CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY,
BY GEO. H. ASHLEY, ASSISTED BY R. W. STONE, CHARLES
BUTTS, AND M. J. MUNN.

PREFACE TO PROGRESS REPORT.

The following preliminary report of progress has been prepared at the request of the Topographic and Geologic Survey Commission. It attempts to give a brief summary of the geologic results of all of the work done under the direction of the Commission and in co-operation with the United States Geological Survey except in four quadrangles at the northern boundary of the State. It covers not only the work upon which publications have already been issued by the Federal Survey, but also, so far as possible, all of the work now in hand. The early part of the co-operative geologic work was in the Pittsburg coal field where the stratigraphy was well understood. Much of the more recent work has been upon the Lower Coal Measures in which the stratigraphic problems are more intricate, and in which hundreds of recent diamond drill records are available. These, while throwing a vast amount of light on the stratigraphy of the Lower Coal Measures have also revealed a large number of incongruities in the former conclusions and have shown much greater variability in the measures than had heretofore been suspected, and since have shown the real difficulties of the problem. For these reasons the satisfactory completion of the work on many of the later quadrangles has been much delayed. It is believed, however, that the most puzzling problems have now been solved, but as it will be some time before all of the reports now in hand can be issued, these results are here presented in a preliminary way. While the matter here given is in a large measure a compilation from reports already published or manuscripts more or less nearly ready for publication, special emphasis is given to some broad generalizations that have been reached within the last year or so as a result of the broad study of certain problems with all of the data obtained up to date. This will be especially noted in the discussion of the stratigraphy,—both the surface and underground stratigraphy, and in the discussion of the occurrence of oil and gas. In several of these lines the report is much more than a summary.

The report has been prepared in a very limited time and will unavoidably bear many marks of haste. It is hoped, however, that this will be more true of the form than of the facts or subject matter. The preliminary portion of the report, dealing with the earlier surveys and their reports, the present Survey and its methods, the general geology of Pennsylvania, the physiography, and the chapter on limestone, has been prepared or compiled by Ralph W. Stone; the portion on the underground stratigraphy by Charles Butts; the portion on the oil and gas by M. J. Munn. The present writer is responsible for the balance of the report and for the plan and ensemble of the whole. The maps and drawings have been made by Dean E. Winchester, A. J. Hazlewood and Samuel D. Shepard.

GEO. H. ASHLEY,
Geologist, U. S. G. S.

Washington, D. C., Aug. 1, 1908.

GEOLOGIC WORK IN PENNSYLVANIA PREPARED BY RALPH W. STONE.

HISTORY OF THE FIRST GEOLOGICAL SURVEY OF PENNSYLVANIA.

Systematic study of the mineral resources of the United States was inaugurated in 1830, when Massachusetts established a Geological Survey. In the decade from 1830 to 1839 fifteen State Geological Surveys were organized, making this a period prominent in the history of the geology of the country. The order of the establishment of these Surveys was as follows: Massachusetts in 1830, Tennessee in 1831, Maryland in 1834, New Jersey, Connecticut and Virginia in 1835, Maine, New York, Ohio and Pennsylvania in 1836, Delaware, Indiana and Michigan in 1837, and New Hampshire and Rhode Island in 1839. Pennsylvania, therefore, was early in the field, and the result of the endeavors of the scientists in her employ to delineate the geology and mineral resources of the State to-day constitutes the largest mass of geological literature yet published by any of the State Surveys. The earliest known printed papers descriptive of the geology of any part of Pennsylvania are, an account of a cascade in the Ohiopyle Falls of the Youghiogheny, by Thomas Hutchens, in 1786, and a note by Thomas P. Smith, calling attention to the "crystalized basaltes" of the Conewago Hills in York county. Both of these notes were published in the Transactions of the American Philosophical Society of Philadelphia. Early interest in the geology of the State is further shown by a sketch of the geology near Easton, Pa., which was written by J. Finch in 1824, and by Prof. Silliman's Notes on the Anthracite Beds in the Lackawanna and Wyoming Valleys, published in 1830. The science of geology was then in its infancy, and but few people in the State were deeply interested in it, although many men were prospecting the wilderness with the hope of discovering valuable mineral deposits. In those days, before the extensive coal and iron beds were known, these prospectors sought diligently up and down the mountains for gold, silver and copper, but in vain.

Appreciating the value of information concerning the geology of the State, a number of men interested in the science, in the spring of 1832 organized the Geological Society of Pennsylvania. The purpose of this Society was the arousing of interest in the mineral resources of the State and the promotion by legislative enactment of a general State Survey. Through the instrumentality of this society an act providing for a geological survey of the State was reported to the Legislature in 1832 and given some consideration. It failed to pass, however, and continued to appear and receive the same treatment annually until the demands of the people became so strong that in 1836 the Legislature passed the bill on the 29th of May. The act inaugurating the survey of the State authorized an annual appropriation of $6,400.00 for five years. It would naturally be expected that some member of the society which had been so actively interested in the promulgation of an act organizing a State Survey would be appointed as State Geologist. However, as not one of the prominent members of the Geological Society of Pennsylvania was fitted by a scientific education to hold such a position, it resulted that the appointment had to be made elsewhere, and Prof. Henry Darwin Rogers, formerly State Geologist of New Jersey, and brother of W. B. Rogers, State Geologist of Virginia, was chosen to occupy this important position. The appropriation permitted of the appointment of assistants, and two were chosen—James C. Booth and John F. Frazier. Dr. Robert E. Rogers was appointed chemist. In the first year of the Survey, by the happy chance discovery of a long series of exposures on Yellow Creek in Huntingdon county, the general geologic order of the rocks in middle Pennsylvania was settled. No important modification in the stratigraphy has been made since then. After a careful study of this section the Paleozoic system was divided into twelve parts, or formations, the lowest being that of the limestone at Harrisburg and Reading, and the highest that of the coal horizon. These formations were designated by numerals, a nomenclature which was used in the Pennsylvania Survey publications for many years. The work of the first field season dissipated many of the fictions which had been promulgated regarding the correlation of certain parts of the coal fields in central Pennsylvania, and also resulted in an understanding of the system of anticlinal and synclinal folds, which play such an important part in the structural geology of the State. In fact, it may be said that American structural geology was born in this first year of the First Geological Survey of Pennsylvania.

In 1837 the appropriation was increased to allow of four assistants, instead of two. As Booth and Frazier had resigned, four new men were needed. At that time the science of geology was taught but little in the colleges, and there were but few men eligible, by reason of their education, to undertake such tasks as were required of the assistants on this Survey. A portion of the summer was lost before the appointments were made. During the second season detailed work was begun in the anthracite region, and it was found that the task of mapping this part of the State at least would be no child's play. An area lying between Easton, Harrisburg, Tioga and Great Bend was examined. Meanwhile, all the counties of the State were demanding, by representatives at Harrisburg, that the Survey should be extended to cover all counties. As a result, in the third year nine assistants were scattered over the State, each man being assigned to a district. Most of the work, as necessarily must be so in the inauguration of such undertakings in a virgin country, was of a reconnaissance nature. At that date much of the northern and western part of the State was an almost unbroken wilderness, roamed over by deer, bear, panther, and other wild beasts. To obtain any idea of the geology of this region required tramping on foot through an unsettled country, with few roads, and the endurance of many hardships. Each assistant had to work alone without books or advisers and to struggle unassisted with the problems as they appeared. The notes thus collected were disconnected and lacking in details, but their volume was enormous. In this year it was first learned that the coal measures of western Pennsylvania are divided into two series, the Upper Productive and the Lower Productive. Also a geologic section was run from the New York State line down the Allegheny River to Pittsburg, and up the Monongahela River to the West Virginia State line. It was found also in 1838 that the bituminous coal field is characterized by folds and basins, but on a broader and simpler plan than in the central part of the State.

It was the plan of Mr. Rogers to continue each of the nine assistants employed in 1838 in the same district in succeeding years. This would be much to the advantage of the work, as familiarity with a region in those early days was a greater aid than now. However, such plans can not always be carried out, by reason of unexpected circumstances, such as death, sickness, or resignations. In the succeeding years of the Survey it was frequently necessary to employ new men to take up the work begun by others, but the plan insisted on by the people of a contemporaneous survey of the entire State was never abandoned.

Each year Mr. Rogers submitted to the Secretary of the Commonwealth an annual report stating briefly the geologic results of the preceding season, but they were not of a character to enlighten the people as to the exact nature, aims and need of the Survey. The result was, that as the desired reports did not appear, and the people could not see that they were getting the worth of their money, in 1842, which would have been the seventh year of the Survey, the

Legislature did not make an appropriation. Mr. Rogers was left without means to carry on the work, but his interest in it was such that he continued for three years, without remuneration from the State, to edit the accumulated wealth of material and prepare it for publication. In 1848 he had prepared a final report and deposited a duplicate of the same with the Secretary of the Commonwealth. An attempt to get the State to publish these results failed, in spite of the fact that it was urged by many that this report contained information which would be of value in the further development of the resources of the State, and which, if left unpublished, would, within a few years, on account of the later developments, be of little value.

It was not until 1851, however, that the Legislature consented to make any further appropriation for the Geological Survey. As the last field work had been done in 1841, the results contained in the report then in the hands of the Secretary were ten years old. The Legislature, therefore, made an appropriation for the continuance of field work for the purpose of bringing the notes up to date and for their publication. Mr. Rogers immediately obtained assistants, and field work was begun in the spring of 1851, particular attention being given to the middle portion of the State, where the development of the anthracite field had been increasing rapidly. Until 1854 at least field work was done each season, but it was not until 1858 that the final report of the Survey appeared. It consists of two quarto volumes containing 1,631 pages, 778 wood cuts, and 43 full page plates made from Lehman's pen and ink sketches of the scenery of the State. Maps, sections and other illustrations were added to these bulky volumes and go to make up a publication remarkable for its day and an honor to its authors.

PUBLICATIONS OF THE FIRST GEOLOGICAL SURVEY OF PENNSYLVANIA.

Annual Reports.

First. 1836. 22 pp.
Second. 1838. 91 pp., 1 pl.
Third. 1839. 119 pp.
Fourth. 1840. 252 pp.
Fifth. 1841. 156 pp., 1 pl.
Sixth. 1842. 28 pp.

Final Reports.

The geology of Pennsylvania, 2 vol.; vol. 1, 586 pp., 7 pl.; vol. 2, 1,045 pp., 30 pl.; atlas of 2 maps, 2 pl. 1858.

HISTORY OF THE SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

In 1873 the annual shipment of anthracite coal from the Schuylkill, Lehigh and Wyoming regions amounted to 21,227,952 long tons. In the same year the production of bituminous coal in Pennsylvania was 13,098,829 short tons. The first oil well was drilled in 1859, and in 1873 the production of the State, together with that from the southern part of New York, amounted to 9,890,964 barrels of crude petroleum. In drilling for oil natural gas was discovered, but up to 1873 had been utilized but little. The production of pig iron in that year, however, amounted to 1,389,573 tons. The people of the State could not fail to take note of the rapid advancement being made in the development of its mineral wealth, which, so far as the above-mentioned commodities are concerned, seemed to be almost unlimited. The years that had passed since the publication of Mr. Rogers' final report in 1858 had brought the State to the forefront in the production of coal and oil, and as a result, the public began to demand later and more detailed information as to the geology and mineral resources. An appeal made to the State for the establishment of a Second Geological Survey resulted in the enactment of a bill which was passed May 14, 1874, and which appointed a Board of Commissioners and authorized the inauguration of a new State Survey. This Commission appointed as State Geologist J. P. Lesley, who had held the position of topographer on the First Survey under Rogers, and had subsequently been topographer and geologist for various private surveys. Leaving this work, however, at the age of twenty-five, he was licensed to preach, and for a number of years was pastor of a Congregational church at Milford, Massachusetts. Giving up religious work in 1851, he returned to Philadelphia and became secretary of the Iron and Steel Association and of the American Philosophical Society. At the time of his appointment as State Geologist he was Professor of Geology in the University of Pennsylvania. Before the end of August, 1874, the following assistants had been appointed: Andrew McCreath, in charge of the iron and steel laboratory at Harrisburg; Dr. F. A.

Genth, chemist and mineralogist; John F. Carll, in charge of the oil districts of western Pennsylvania; Henry E. Wrigley, to prepare a special economic report on the petroleum of Pennsylvania; Franklin Platt, in charge of the Clearfield and Jefferson bituminous coal district; Persifor Frazer, Jr., in charge of the York and Adams district; Frederick Prime, Jr., in charge of the Lehigh district, and John H. Dewees, in charge of the Juniata district.

A number of experienced civil engineers were appointed to the field parties, and the work of the Second Survey was begun most auspiciously. After the purchase of all the instruments required for the various parties and the equipment of the iron and steel laboratory and cabinet rooms at Harrisburg, which consumed about $5,000, there remained about $30,000 for the actual business of the Survey. The plans adopted for this new undertaking included the following points: (1) The occupation of five specially important, and hitherto little studied, districts of the State requiring immediate attention; (2) the postponement of work in the best known anthracite and bituminous coal regions; (3) the postponement of extensive systematic study of fossils; (4) the establishment of a special laboratory at Harrisburg for the analysis of irons, steels, iron ores, and other blast-furnace stock (5) a special report on petroleum; (6) a special report on the minerology of the State; (7) the publication of the results of the summer's work during the following winter, and (8) the exhibition of type specimens of the Survey collections in the rooms of the Board at Harrisburg.

As a reconnaissance geologic survey of the entire State had already been made and the general geology was known with a surprising degree of accuracy, as was found later by the assistants of this Second Survey, the problems to be undertaken under Lesley's direction were well understood and plans could be made accordingly. A special note book was devised, and all the assistants were required to use the same field methods. Certain fixed scales were adopted for plotting road sections and traversed lines, another scale for geologic sections, and a strict adherence to these was insisted upon. This new Survey was to study the details of special geologic problems rather than the broad features of the entire State, and for that reason the field parties were equipped with instruments of precision, including transits, surveyor's compass, odometer, Locke levels, clinometers, etc. Base lines in the district were run and leveled along selected main roads, which were much more numerous than in the days of the First Survey.

During the thirteen years that the Second Survey existed, annual appropriations were made which amounted to $545,000.00. Among those who were regularly employed or undertook special investigations in association with Lesley were: C. A. Ashburner, C. E. Beecher, J. C. Branner, J. F. Carll, H. M. Chance, E. W. Claypole, E. V. d'Invilliers, L. G. Eakins, Persifor Frazer, F. A. Genth, C. E. Hall, T. S. Hunt, A. E. Lehman, Leo Lesquereux, A. S. McCreath, F. Prime, Jr., J. J. Stevenson, I. C. White, Arthur Winslow and G. F. Wright.

The principal work of the organization was the solution of economic problems, particularly of structural details, and of the extent of the coal and petroleum formations. More attention was given to chemical and physical researches than to palentology. Lesley's aim is expressed in the following letter:

> "I have been obliged for the last fourteen years to direct the State Survey almost exclusively in an economic direction, so as to make the whole of every appropriation bring as much fruit to the business community as possible, neglecting, in what systematic geologists may possibly or probably consider a shameful manner, strictly scientific researches. Even when I have ordered long and extensive researches (as in the case of the analyses of the Lower Silurian limestone series opposite Harrisburg) it has been, not in the spirit of transcendental science, but with the express intention to use the results directly as applied science to the economical demands of the State. It can hardly be understood by outsiders how completely a State bureau is shut up to this necessity."

The reports of Lesley's associates were published as rapidly as they could be prepared, as the experience of the First Survey showed the dangers of delay. They proved of considerable value to the public, particularly to those engaged in mining, and no doubt fully justified the large expenditure of the State funds, amounting to over one-half million dollars. The fundamental defect of the work of the Second Survey, as shown by the work of recent years, was a lack of accurate topographic maps. Structural work by Federal geologists in the past ten years has shown that in the western counties the geologists of the Second Survey placed too much dependence on the northeast-southwest trend of the structures. Anticlinal and synclinal axes were drawn on the Second Survey maps with a straight ruler, and are, therefore, erroneous and misleading. The geologists who connected the folds and basins along the strike with such unjustified freedom and directness evidently did not trace the structure carefully from point to point, for even with the poor base maps which they used the curving character of these axes would have been determined had they been followed. The delineation of the structure by contour lines could not have been done, however, in the time of the Second Survey, with the accuracy of the work of recent years, for deep well records and mine data were not then so abundant.

The results of the field work, which continued uninterruptedly from 1874 to 1887, are contained in 77 octavo volumes of text, with 35 atlases, and a "Grand Atlas." These were published as rapidly as they could be prepared during the progress of the Survey, and were followed in 1893 and 1895 by the 3 octavo volumes constituting the final report. With the publication of the third volume of the final report in 1895, the Second Geological Survey of Pennsylvania came to an end.

PUBLICATIONS OF THE SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA.

Neither the State of Pennsylvania nor the U. S. Geological Survey have any of these reports for distribution. They can only be obtained from second hand book dealers.

ANNUAL REPORTS.

1885—769 pp. 8 pl., and maps; contains following special reports:

1. Oil and Gas. John F. Carll.
2. Vegetable Origin of Coal. Leo Lesquereux.
3. Pittsburg Coal Region. E. V. d'Invilliers.
4. Wellersburg Coal Basin. J. P. Lesley and E. B. Harden.
5. Tipton Run Coal Basin. C. A. Ashburner.
6. Anthracite Coal Region. C. A. Ashburner.
7. Wyoming Valley Fossils. C. A. Ashburner and A. Heilprin.
8. Bernice Coal Basin. C. A. Ashburner.
9. Mehoopany Coal Field. F. A. Hill.
10. Cornwall Ore Mines. J. P. Lesley and E. V. d'Invilliers.
11. Delaware and Chester Kaolins. J. P. Lesley and C. A. Ashburner.
12. Quarternary Geology, Wyoming Valley. C. A. Ashburner, F. A. Hill and H. C. Lewis.
13. Pressure, &c., of Rock Gas. J. P. Lesley.
14. Progress Geodetic Survey. Mansfield Merriman.

1886—4 parts, as follows:

i. Pittsburgh Coal Region. E. V. d'Invilliers.
ii. Oil and Gas Region. J. F. Carll, F. C. Phillips, B. S. Lyman.
iii. Anthracite Coal Region with Atlas. F. A. Hill.
iv. 1. The Lehigh River Cross Section. Arthur Winslow.
    2. Paint Ores along the Lehigh River. F. A. Hill.
    3. Iron Ore Mines and Limestone Quarries of the Cumberland-Lebanon Valley. E. V. d'Invilliers.
    4. Geology of Radnor township, Delaware Co., &c., T. D. Rand. With an Atlas.

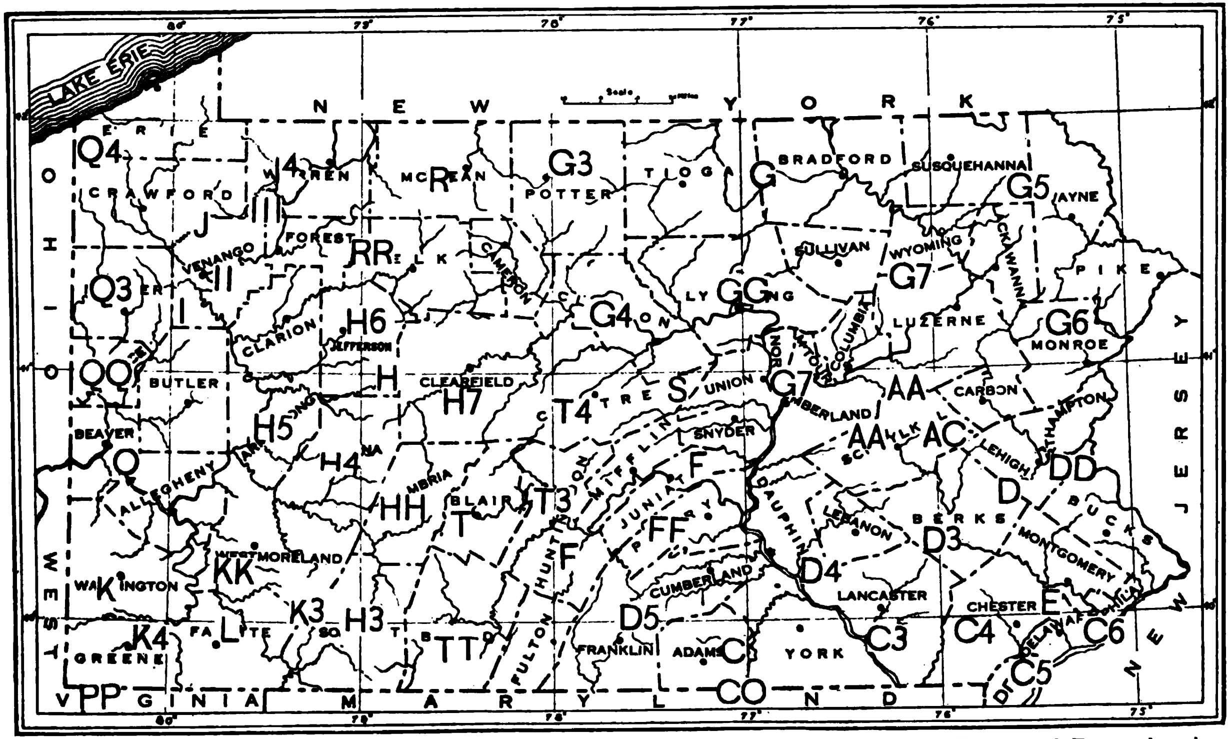

Plate II. Key map showing areas covered by publications of the Second Geological Survey of Pennsylvania.

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1887—105 pp., map New Boston Anthracite basin.

1. Cave Fossils. Prof. Joseph Leidy.
2. Fossil tracks in the Trias. Atreus Wanner.
3. New Boston Anthracite Basin. Benj. Smith Lyman.
4. State Line Serpentine. Prof. F. D. Chester.

MISCELLANEOUS REPORTS.

A. A history of First Geological Survey of Pennsylvania, from 1836 to 1858, J. P. Lesley; with annual reports of Board to Legislature for 1874 and 1875. 226 pp. 1876.

B. Minerals of Pennsylvania, F. A. Genth; hydro-carbon compounds, S. P. Sadtler; reference map. 206 pp. 1875.

B2. Minerals, F. A. Genth, continued from page 207 to 238. 31 pp. 1876. (Bound with B.)

M. Chemical Analyses in 1874-5, A. S. McCreath. 105 pp. 1875.

M2. Chemical Analyses in 1876-8, A. S. McCreath; Classification of coals, P. Frazer; Fire-brick tests, F. Platt; Dolomitic limestone beds, J. P. Lesley; Utilization of anthracite slack, F. Platt; Determination of Carbon in iron or steel, A. S. McCreath. 1 folded pl., 4 page pls. 438 pp. 1879.

M3. Chemical Analyses in 1879-80, A. S. McCreath; reference map of 93 iron ore mines in Cumberland Valley. 126 pp. 1881.

N. Levels above tide of railroads, canal and turnpike stations, mountain tops, &c., in and around Pennsylvania, 200 tables, C. Allen; map. 279 pp. 1878.

O. Catalogue of specimens collected by survey (No. 1 to 4,264), C. E. Hall. 217 pp. 1878.

O2. Catalogue (continued from No. 4,265 to No. 8,974); also catalogue of fossils (pp. 231 to 239.) 272 pp. 1880.

O3. Catalogue (continued from No. 8,975 to No. 12,872); also catalogue of special collections of fossils in stratigraphical order, from 201-1 to C7-4-3; and Revised Catalogue of Randall's collection, from 9,467 to 9,625. 260 pp. 1889.

P. Coal Flora of Pennsylvania and the United States. Vols. 1 and 2 (bound together), L. Lesquereux. 694 pp. 1880.

P. Coal Flora of Pennsylvania and the United States. Vol. 3, 24 double page pls. (lithographed) of coal plants, to accompany P., vols. 1 and 2. 283 pp. 1884.

(P). Atlas of 87 double page pls. (lithographed) of coal plants to accompany P., vols. 1 and 2. 1879.

P2. Permo-Carboniferous plants from W. Va. and Greene county, Pa., W. M. Fontaine and I. C. White. 38 double page pls. (lithographed). 143 pp. 1880.

P3. Ceratiocaridae, C. E. Beecher; Eurypteridae, James Hall. 8 pls. 39 pp. 1884.

P4. Dictionary of Fossils found in Pa. and alsewhere, with electrotype illustrations of the various forms. 2 vols. and appendix, J. P. Lesley. pp. 800. 1889.

X. Geological Hand Atlas of the 67 counties of Pa., with short explanation of the geological structure of each county, embodying results of field work of the survey from 1874 to 1884, J. P. Lesley. 62 colored maps and cross section. 112 pp. 1885.

Z. Terminal Moraine across Pennsylvania, H. C. Lewis; extracts from descriptions of the Moraine in New Jersey, G. H. Cook, and in Ohio, Kentucky and Indiana, G. F. Wright. Map of State, 18 photographic views of the Moraine, and 32 page plate maps and sections, pp. lvi and 299. 1884.

Grand Atlas, Div. I, Pt. I, 1885, port-folio containing maps of 56 counties and parts of counties (scale 2 mi. to 1 inch) on 49 sheets (26″ x 32″.)

Annual Report, Pt. IV. 1886.

SUMMARY REPORT.

Vol. I. Laurentian, Cambrian, Lower Silurian. J. P. Lesley, pp. 1-719, 1892.

Vol. II. Upper Silurian and Devonian. J. P. Lesley, pp. 721-1628, 1893.

Vol. III, part 1. Carboniferous. J. P. Lesley, E. V. d'Invilliers, and A. D. W. Smith, pp. 1629-2152, 1895.

Vol. III, part 2. Carboniferous, New Red. E. V. d'Invilliers and Benjamin Smith Lyman, pp. 2153-2638, 1985.

These volumes give in a condensed form a summary of practically all of the preceding publications, with some additional matter of later date, including a new geologic map of the State, a map and list of bituminous mines, and 611 page plates.

Index of Final Summary Report, Wm. A. Ingham, pp. 1-98, i-xxx, 1895.

ANTHRACITE REGION.

A2. Causes, kinds and amount of waste in mining anthracite, F. Platt; Methods of mining (1 chapter), J. P. Wetherill, illustrated by 35 figures of mining operations, plan of the Hammond breaker, and specimen sheet of the maps of the Anthracite coal fields. 134 pp. 1881.

AC. Mining Methods, &c., in the anthracite coal fields, H. M. Chance. 54 pls. and 60 illustrations in text. 574 pp. 1883. Atlas containing 25 pls. illustrating coal mining.

AA. First report of progress of the anthracite survey; Panther Creek Basin, C. A. Ashburner; determination of the latitude and longitude of Wilkes-Barre and Pottsville, C. L. Doolittle; theory of stadia measurements, A. Winslow. 407 pp. 1883.

AA. Second report of progress of the anthracite survey, Pt. I; Statistics of Production and Shipment for 1883 and 1884, C. A. Ashburner.

(AA). Atlas of Southern anthracite field, Pt. I, 13 sheets; 3 geological and mine sheets, 3 cross section sheets, 3 columnar section sheets, 1 topographical map sheet, and 1 coal bed area sheet, relating to the Panther Creek Basin; 1 general map of the anthracite region, and 1 chart of anthracite production from 1820 to 1881; C. A. Ashburner, A. W. Sheafer, and F. A. Hill. 1882.

(AA). Atlas Southern anthracite field, Pt. II, 13 mine sheets between Tamaqua and Tremont, F. A. Hill, and A. D. W. Smith. 1889.

(AA). Atlas Southern anthracite field, Pt. III, 12 mine sheets between Tremont and western end of the southern basin, and a general map of the anthracite fields showing the location of collieries. F. A. Hill and A. D. W. Smith. 1889.

(AA). Atlas Southern anthracite field, Pt. IV.

(AA). Atlas of Western Middle anthracite field, Pt. I, 11 sheets; 4 geological and mine sheets between Delano and Locust Dale, 3 topographical sheets between Quakake Junction and Mount Carmel, and 4 cross section sheets. C. A. Ashburner, A. W. Sheafer, and Bard Wells. 1884.

(AA). Atlas of Western Middle anthracite field, Pt. II, 11 sheets; 4 geological and mine sheets from Mount Carmel to the western end of the coal field, and 7 columnar section sheets covering the entire field. F. A. Hill and Bard Wells. 1887.

(AA). Atlas of Western Middle anthracite field, Pt. III.

(AA). Atlas of Northern anthracite field, Pt. I, 6 geological and mine sheets between Wilkes-Barre and Nanticoke, 3 cross section sheets and 4 columnar section sheets, C. A. Ashburner, and F. A. Hill. 1885.

(AA). Atlas of Northern anthracite field, Pt. II, 10 sheets; 4 mine sheets relating to that portion of the Wyoming-Lackawanna coal basin between Wyoming and Taylorville, and 2 topographical and mine sheets relating to the extreme western end of the Wyoming basin; 4 columnar section sheets of boreholes, shafts, and tunnels; F. A. Hills, and William Griffith. 1887.

(AA). Atlas of Northern anthracite field, Pt. III, 8 sheets; 4 mine, and 4 columnar section sheets relating to that portion of the Lackawanna basin in the vicinity of Taylorville, Minooka, Scranton, Dunmore and Priceville; F. A. Hill and William Griffith. 1889.

(AA). Atlas of Northern anthracite field, Pt. IV, 8 mine sheets relating to that portion of the Lackawanna basin in the vicinity of Olyphant, Peckville, Jessup, Winton, Archbald, Jermyn, Glenwood, Carbondale, and Forest City in Lackawanna and Susquehanna counties; F. A. Hill and William Griffith. 1889.

(AA). Atlas of Northern anthracite field, Pt. V.

(AA). Atlas Eastern Middle anthracite field, Pt. I, 8 sheets; 2 geological and mine sheets in the vicinity of Hazleton, Drifton and surrounding towns, 3 cross section sheets and 3 columnar section sheets; C. A. Ashburner, A. P. Berlin and Arthur Winslow. 1885.

(AA). Atlas of Eastern Middle anthracite field, Pt. II, 8 sheets; 6 mine, and 2 columnar section sheets relating to portions of the Lehigh basins in the vicinity of Upper Lehigh, Pond Creek, Sandy Run, Eckley, Weatherly, Buck Mountain, Beaver Meadow, Coleraine, Jeansville and Audenried, in Luzerne, Carbon and Schuylkill counties; F. A. Hill and I. R. Moister. 1888.

(AA.) Atlas Eastern Middle anthracite field, Pt. III, 13 sheets; 8 mine sheets, covering the entire western part of the field, 2 columnar section sheets and 3 cross section sheets; F. A. Hill and I. R. Moister. 1889.

Grand Atlas, Div. II, Pt. I. 1884. Port-folio containing 26 sheets (26" x 32"), as follows: 13 sheets Atlas Southern Anthracite Field, Pt. I. 11 sheets Atlas Western Middle Anthracite Field, Pt. I, 1 sheet photo views of plaster models in Western, Middle and Southern Fields, and 1 specimen sheet, Report A2.

Grand Atlas, Div. II, Pt. II, 1885. Port-folio containing 22 sheets (26" x 32"), as follows: 13 sheets Atlas Northern Anthracite Field, Pa. I, 8 sheets Atlas Eastern Middle Anthracite Field, Pt. I, and 1 sheet containing a preliminary general map of the Anthracite Coal Fields and adjoining counties.

For Anthracite coal in Sullivan county, see G2 and Annual Report, 1885.

For Utilization of anthracite slack, see M2.

For General description anthracite region, Quaternary Geology of the Wyoming-Lackawanna Valley, &c., &c., see Annual Report, 1885.

Annual Report, Pt. III. 1886.

BITUMINOUS COAL FIELDS AND SURROUNDING AREAS.

H. First report on Clearfield and Jefferson counties, F. Platt. 8 maps, 2 sections, 139 cuts in text. 296 pp. 1875. (For second report, see H 6, H 7.)

H 2. Cambria county, F. & W. G. Platt. 4 maps and sections, and 84 cuts in text. 194 pp. 1877.

H 3. Somerset county, F. & W. G. Platt. 6 maps and sections and 110 cuts in text. 348 pp. 1877.

Atlas to Reports H2 and H3 containing geological maps of Cambria and Somerset counties, with 2 sheets of columnar sections and 1 cross section; a revision and correction of the semi-bituminous coal section at Wellersburg, Somerset county, and notes on the new mines in Cambria county. 1889.

H 4. Indiana county, W. G. Platt. Colored geological map and 87 cuts in text. 316 pp. 1878.

H 5. Armstrong county, W. G. Platt. Colored geological map and 58 cuts in text. 338 pp. 1880.

H 6. Jefferson county, W. G. Platt. Colored geological map and 57 cuts in text. 218 pp. 1881.

H 7. Clearfield county, H. M. Chance. Colored geological map, an outcrop map of Houtzdale basin, and 58 cuts in text. 197 pp. 1884.

I. Venango county, J. F. Carll; The geology around Warren, F. A. Randall; Notes on the comparative geology of N. E. Ohio, N. W. Pa., and W. New York, J. P. Lesley. 1 small map of the Venango oil region, 1 small map of the region south and east of Lake Erie, 1 long section of the rocks at Warren, and 7 cuts in text. 127 pp. 1875.

I 2. Oil well records and levels in Venango, Warren, Crawford, Clarion, Armstrong, Butler, &c., J. F. Carll. 398 pp. 1877.

I 3. Venango, Warren, Clarion, and Butler Oil Regions; descriptions of rig, tools, &c., survey of the Garland and Panama conglomerates, &c.; discussion of pre-glacial and post-glacial drainage; J. F. Carll. 23 page plates and an atlas. 482 pp. 1880.

(I 3.), Atlas of 22 sheets. Map of Venango county, colored geologically; map lower oil field (Butler, Armstrong, and Clarion) in two sheets; 3 local contour maps at Franklin, Titusville and Spring Creek; 2 maps of N. W. Pennsylvania, showing past and present drainage; long section across W. Pennsylvania; vertical section of the formations from the Upper Coal measures down to the bottom of the Devonian; diagram map and section of Third sand; profile section from Meadville, S. W.; 5 sheets of grouped oil well sections; 5 sheets of working drawings for well boring, &c.; diagram of daily rate of drilling six wells at Petrolia.

I 4. Warren county, J. F. Carll. Colored geological map, map of Warren oil region, and 2 sheets of oil well sections. 439 pp. 1883. (Note—The first 147 pages of this book contain oil well records.)

J. The Oil Region, H. E. Wrigley; map and profile of line levels through Butler, Armstrong, and Clarion, D. J. Lucas; map and profile of Slippery Rock creek, J. P. Lesley. 5 maps and sections, 1 pl. and 5 cuts. 122 pp. 1875.

K. Greene and Washington counties, J. J. Stevenson. 2 maps. (Showing the calculated local depths of the Pittsburg and Waynesburg coal beds beneath the surface), 3 page plates of general sections. 419 pp. 1876. (Note—Since publication of this book two colored geological county maps have been published, and will be found in pocket of vol. K3.)

K 2. First report on Fayette, Westmoreland, and S. E. Allegheny counties (i. e., west of Chestnut Ridge), J. J. Stevenson. 3 colored geological maps and 50 cuts in text. 437 pp. 1877.

K 3. Second report on Fayette and Westmoreland counties (the Ligonier Valley), J. J. Stevenson. 4 page plates and 107 cuts in text. 331 pp. 1878.

K 4. Monongahela River Coal Mines, from West Virginia State Line to Pittsburgh (including some on the Youghiogheny and other streams), J. Sutton Wall. Map of region in pocket, 12 heliotype pictures, 26 page plates. 231 pp. 1884.

L. Youghiogheny coke manufacture, F. Platt; Notes on the coal and iron ore beds, C. A. Young; Report on methods of coking, J. Fulton; Report on the use of natural gas in the iron manufacture, J. B. Pearse and F. Platt; The Boyd's Hill gas well at Pittsburgh, J. P. Lesley. Map of the coke region, two folded plates of coke ovens, and page plates and cuts in text. 252 pp. 1876.

Q. Beaver, N. W. Allegheny and S. Butler counties, I. C. White. 3 colored geological county maps, and 21 page plates of sections. 337 pp. 1878.

Q 2. Lawrence county, and special Report on Correlation of the Pennsylvania and Ohio coal beds, I. C. White. Colored geological map (county) and 134 cuts in text. 336 pp. 1879.

Q 3. Mercer county, I. C. White. Colored geological county map and 119 cuts in text. 233 pp. 1880.

Q 4. Crawford and Erie counties, I. C. White. 2 colored geological county maps and 107 cuts in text. Also, report on a pre-glacial outlet for Lake Erie, J. W. Spencer. 2 maps of the Lake region. 406 pp. 1881.

R. McKean county, and its geological connections with Cameron, Elk, and Forest counties, C. A. Ashburner. 33 page plates of vertical and columnar sections, pictures of Rock City and Olean conglomerate, Wilcox and Kane spouting wells, map of Howard Hill coal field, &c., and an atlas of 8 sheets. 371 pp. 1880.

(R.) Atlas for McKean county of 8 sheets; colored geological county map; 3 topographical maps; Buffalo Coal Company tract, Alton coal basin, and Potato Creek coal basin; map of McKean oil district; one sheet of colmunar sections between Bradford and Ridgway and 2 diagram sheets of the Well account and Production account in the Bradford district.

R 2. Pt. II, report on township geology of Cameron, Elk and Forest counties, C. A. Ashburner.

(R 2.) Atlas for Cameron, Elk and Forest counties, of 11 sheets (published November, 1884, in advance of the report); 3 colored geological county maps; 1 anticlinal and synclinal map; 1 topographical map McKean county; 2 tract maps Forest and Elk counties; 1 map Straight Creek coal basin; 2 sheets oil well sections; and 1 sheet coal sections.

V. N. Butler county; and (Pt. II) special report on the Beaver and Shenango river coal measures, H. M. Chance. Colored geological map of N. Butler; contour local map around Parker; map of the anticlinal rolls in the 6th basin; chart of the Beaver and Shenango rivers; profile section from Homewood to Sharon; oil well records and surface sections; and 154 cuts in text. 248 pp. 1879.

V 2. Clarion county, H. M. Chance. Colored geological county map; map of the anticlinals and oil belt; contoured map of the old river channel at Parker; 4 page plates, and 83 cuts in text. 232 pp. 1880.

For the coal basins of Bradford and Tioga counties, see report G.

For the coal basins of Lycoming and Sullivan, see report G 2.

For the coal basins of Potter county, see G 3.

For the coal basins of Clinton county, see G 4.

For the coal in Wayne county, see G 5 and Northern Atlas, Part IV.

For the East Broad Top coal basin in Huntingdon county, see F.

For the mountain coals in Blair county, see T.

For the Broad Top coal measures in Bedford and Fulton counties, see T 2.

For the coal basins in Centre county, see T 4.

For coal analyses, see M, M 2, M 3.

For classification of coals, see M 2.

For coal plants, see P, P 2.

For fossil crustacens in coal slate, see P 3.

For origin of coal; Pittsburg Region and Monongahela Valley; Wellersburg coal basin, Somerset county; and Tipton Run coal beds, Blair county; see Annual Reports, 1885, and Atlas H 2 and H 3.

Grand Atlas, Div. III, Pt. I, 1885; port-folio containing 35 sheets (26" x 32"), as follows: 32 sheets relating to portions of the Petroleum and Bituminous Coal Fields, and 3 sheets relating to the Quaternary period.

Annual Report, 1886. Part I.

PETROLEUM AND GAS.

See reports I, I 2, I 3, I 4, and J, under Bituminous Coal Fields.

See L for the Pittsburgh gas well, and the use of gas in iron manufacture.

See Q, Q 2, Q 3, Q 4, for references to oil rocks in Beaver, Lawrence, Mercer, Crawford, Erie, and S. Butler counties.

See K for the Dunkard Creek oil wells of Greene county.

See R, R 2, for descriptions of oil rocks in McKean, Elk, and Forest counties.

See V, V 2, for notes on the oil rocks of N. Butler and Clarion counties.

See H 2 for oil boring at Cherry Tree, Cambria county.

See G 5 for oil boring in Wayne county.

See Annual Report, 1885, for report of progress in the oil and gas region, with special facts relating to the geology and physics of natural gas.

See Grand Atlas, Div. III, Pt. I, under Bituminous Coal Fields.

See Annual Reports, 1886. Part II.

NORTHEASTERN AND MIDDLE PENNSYLVANIA.

(Palaeozoic formations from the Coal Measures down.)

D. First report on Lehigh county iron mines, F. Prime. Contour line map of the ore region and 8 page plates. 73 pp. 1875.

D 2. Second report on Lehigh county iron mines, F. Prime. Colored geological contour line map of the iron region (in 4 sheets), colored geological contour line map of the Ironton mines, 4 double page lithograph pictures of Limestone quarries, and 1 page plate of Monocraterion. 99 pp. 1878.

D 3. Vol. I. Lehigh and Northampton counties. Introduction by J. P. Lesley; Slate belt, R. H. Sanders; Limestone belt and iron mines, F. Prime; South Mountain rocks, F. Prime and C. E. Hall. 3 lithograph pictures of quarries, 4 pictures of triangulation stations, 14 page plates of sections, and an atlas of maps. 283 pp. 1883. (Note—For atlas, see below.)

D 3. Vol. II. Berks county (South Mountain belt), E. V. d'Invilliers. 10 pages plates of sections and Indian relics, and 3 pictures of rock exposures. 441 pp. 1883. (Note—For atlas, see below.)

(D 3) Atlas; 1 colored geological map of Lehigh and Northampton counties (1 sheet); 1 colored geological contour line map of southern Northampton county (6 sheets); a contour line map of the mountains from the Delaware to the Schuylkill (18 sheets); colored geological contour line index map to the 22 sheets (1 sheet); and 4 sheets of maps of iron mines.

(D 5) Atlas of colored geological county maps of Cumberland, Franklin and Adams (3 sheets); and first installment of contour line map of the South Mountains, Sheets A 1, A 2, B 1, B 2 (4 sheets), A. E. Lehman.

F. Juniata River district in Mifflin, Snyder, and Huntingdon counties, J. H. Dewees; The Aughwick Valley and East Broad Top region in Huntingdon county, C. A. Ashburner. Colored geological maps of East Broad Top R. R. and Orbisonia vicinity (2 sheets); Three Springs map and section (2 sheets); Sideling Hill Creek map and section (2 sheets), and Isometric projection at Three Spirngs (1 sheet); six folded cross sections, and 22 page plates of local maps and columnar sections. 305 pp. 1878.

F 2. Perry county (Pt. I, geology), E. W. Claypole. 2 colored geological maps of the county; 17 geological outline township maps as page plates, and 30 page plate cross and columnar sections. 437 pp. 1884.

G. Bradford and Tioga counties, A. Sherwood; report on their coal fields (including forks of Pine Creek in Potter county), F. Platt; report on the coking of bituminous coal, J. Fulton. (See L above.) 2 colored geological county maps, 3 page plates, and 35 cuts in text. 271 pp. 1878.

G 2. Lycoming and Sullivan counties; field notes by A. Sherwood; coal basins, by F. Platt. 2 colored geological county maps (of Lycoming and Sullivan); topographical map (in 2 sheets) of the Little Pine Creek coal basin; and 24 page plates of columnar sections. 268 pp. 1880.

G 3. Potter county, A. Sherwood; report on its coal fields, F. Platt. Colored geological county map, 2 folded plates and 2 page plates of sections. 121 pp. 1880.

G 4. Report on Clinton county, H. M. Chance, including description of the Renovo coal basin, C. A. Ashburner, and notes on the Tangascootac coal basin, F. Platt. Colored geological county map, 1 sheet of sections, local Renovo map, 6 page plates, and 21 sections in text. 183 pp. 1880.

G 5. Susquehanna and Wayne counties, I. C. White. Colored geological map of the two counties and 58 cuts in text. 243 pp. 1881.

G 6. Pike and Monroe counties, I. C. White. 2 colored geological county maps (1 sheet Pike and Monroe and 1 sheet Wyoming); map of glacial scratches, and 7 small sections. Report on the Delaware and Lehigh Water Gaps, with two contoured maps and five sections of the gaps, H. M. Chance. 407 pp. 1882.

G 7. Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland counties (i. e., the parts lying outside of the anthracite coal fields), I. C. White. Colored geological map of these counties (in 2 sheets), and 31 page plates in text. 464 pp. 1883. (Note—The colored geological map of Wyoming county is published in G 6.)

T. Blair county, F. Platt. 35 cuts in text and an atlas of maps and sections (see below). 311 pp. 1881.

(T) Atlas of colored geological contour line map of Morrison's Cove, Canoe Valley, Sinking Valley, and country west to the Cambria county line (14 sheets); index map of the same (1 sheet); colored sections (2 sheets). 1881.

T 2. Bedford and Fulton counties, J. J. Stevenson. 2 colored geological maps of the two counties. 382 pp. 1882.

T 3. Huntingdon county, I. C. White. Colored geological map of the county, and numerous sections. 471 pp. 1885.

T 4. Centre county, E. V. d'Invilliers; also special report, A. L. Ewing, and extracts from report to Lyon, Shorb & Co., by J. P. Lesley. Colored geological map of the county, 13 page plates of local maps and sections, and 15 cuts in text. 464 pp. 1884.

For report on line of the Terminal Moraine, see Z.

Grand Atlas, Div. IV, Pt. I, 1885. Port-folio containing 43 sheets, as follows: 30 sheets relating to the Durham and Reading Hills and bordering valleys in

Northampton, Lehigh, Bucks and Berks counties, and 13 sheets relating to the South Mountains in Adams, Franklin, Cumberland and York counties.

Grand Atlas, Div. V, Pt. I, 1885. Port-folio containing 35 sheets, as follows: 29 sheets relating to the Topography and Geology of the Palaeozoic strata in parts of Cambria, Blair, Bedford, Huntingdon, Mifflin, Centre and Union counties, 5 sheets containing map and geological cross section along the east bank of the Susquehanna River, Lancaster county, and 1 sheet containing cross sections of the Philadelphia belt of the Azoic rocks.

For report on Cornwall Iron Ore Mines, Lebanon county, and the Tipton Run coal beds, Blair county, see Annual Report, 1885.

For report on the Iron Ore Mines and Limestone Quarries of the Cumberland-Lebanon Valley, and Paint-ore along the Lehigh River, see Annual, 1886, Part IV.

SOUTHEASTERN PENNSYLVANIA.

C. York and Adams counties, P. Frazer. 1 folded map of a belt of York county through York and Hanover, 6 folded cross sections, and 2 page plate microscopic slices of dolerite. 198 pp. 1876. (Note—The colored geological county map of York is published in the Atlas to C 3.)

C 2. York and Adams counties (South Mountain rocks, iron ores, etc.), P. Frazer. 1 general map of the district, 10 folded cross sections, and 5 page plates. 400 pp. 1877. (Note—The colored geological county map of Adams is published in D 5.)

C 3. Lancaster county, P. Frazer. 9 double page lithographic views of slate quarries and Indian-pictured rocks, 1 plate of impressions on slate, and 1 page plate microscopic section of trap, and an atlas. 350 pp. 1880.

(C 3) Atlas of 13 sheets: Colored geological map of York county; colored geological map of Lancaster county; Susquehanna River section. (Sheets 1, 1A, 2, 2A, 3, 4); Lancaster section; Pequea section; Muddy Run section; Chestnut Hill mines; Gap Nickel mine.

C 4. Chester county; general description, 214 pp., J. P. Lesley; Field notes in the townships, 139 pp., P. Frazer. Colored geological county map, photographic view of contorted schists, and 12 page plates. 394 pp. 1883.

C 5. Delaware county, C. E. Hall. Colored geological county map; 30 photographic page plate views of granite quarries, kaolin pits, etc., and 4 page plates of altered mica. 128 pp. 1885. See Annual Report, 1885, for Kaolin report.

C 6. Philadelphia and the southern parts of Montgomery and Bucks counties, C. E. Hall. Colored geological map of the belt of country between Trenton and Delaware county (in 3 sheets), a sheet of colored cross sections and 24 cuts in text. 145 pp. 1882.

(C 7) Atlas to report on Bucks and Montgomery counties, containing 12 sheets of topographical map of the Neshaminy, Tohickon and Perkiomen water basins by the Philadelphia Water Department on a scale of 1,600 feet to 1 inch, 1-19600 of nature. 1887.

E. Part I (historical introduction to) of a report on the Azoic rocks, T. S. Hunt. 253 pp. 1878.

For report on the kaolin deposits of Chester and Delaware counties, see Annual Report, 1885.

For report on the Serpentines of Radnor township, Delaware Co., etc., see Annual, 1886, Part IV.

See also Grand Atlas, Div. V, Pt. I, under Northeastern and Middle Pennsylvania.

CO-OPERATIVE WORK BETWEEN THE TOPOGRAPHIC AND GEOLOGIC SURVEY COMMISSION OF PENNSYLVANIA AND THE UNITED STATES GEOLOGICAL SURVEY.

A number of years after the discontinuance of the Second Geological Survey of Pennsylvania the people of the State began to appreciate the desirability of having an accurate topographical map, and as the United States Geological Survey had offered to co-operate with any of the States which wished to carry on geologic and topographic work, the Legislature passed an act April 28, 1899, authorizing a Topographic and Geological Survey of the State in co-operation with the United States Geological Survey. This act authorized the Governor to appoint a commission of three citizens of the State, who should serve without pay, but with all necessary expenses paid out of the State Treasury, and who should have power to arrange with the Director of the United States Geological Survey for the execution of the purpose of the act. For the prosecution of this Survey the sum of $20,000 was appropriated for the year 1899, and $20,000 for the year 1900, on the condition that these sums should be duplicated by the United States Geological Survey. The Governor appointed Geo. W. McNees, Simon Harrold and Fred. D. Barker as Topographic Survey Commissioners, and on July 12, 1899, they entered into an agreement with the Director of the United States Geological Survey for co-operative topographic and geologic work. Under the terms of this agreement, the expense of the field work of all kinds and of the office work in the preparation of the manuscript maps and the reports of the geologic work is borne jointly by the United States Geological Survey and the State of Pennsylvania, but all additional work and expense incident to the printing of the maps and reports is borne by the United States Geological Survey alone. The scientific control of this work rests entirely with the Director of the Federal Survey, but the order in which the work shall be undertaken in the State is determined by agreement with the Commission. The supervision of the co-operative geologic work in Pennsylvania, from its inception in 1900, has been in charge of M. R. Campbell, who gave it active field supervision until 1904. Since that time Geo. H. Ashley has been actively in charge.

Geologic field work on the co-operative plan began July 1, 1900. Operations since that date are briefly recorded as follows:

Field Season 1900.—The Uniontown and Masontown quadrangles were mapped by M. R. Campbell, assisted by J. D. Irving and M. L.

Fuller. On the completion of that work, the party moved to the Gaines and Elkland quadrangles September 1, where they were joined by Chas. Butts, who had for some time been studying the geology of the adjacent regions of New York, and by Wm. C. Alden, who mapped the glacial geology of those quadrangles. Mr. Fuller also examined the Gaines oil field, just south of the Gaines quadrangle, and prepared a report on it.

Field Season 1901.—The Brownsville and Connellsville quadrangles were surveyed by M. R. Campbell, assisted by Chas. Butts, L. H. Woolsey and L. C. Glenn. Later in the season Mr. Campbell surveyed the Latrobe quadrangle, assisted by Mr. Woolsey and G. B. Richardson. Mr. Richardson mapped the Indiana quadrangle, and Mr. Fuller, assisted by F. G. Clapp, did further work on the Elkland and Tioga quadrangles. Later in the season work on the Kittanning quadrangle was begun by Messrs. Campbell, Butts and Woolsey.

Field Season 1902.—The Kittanning and Rural Valley quadrangles were completed by Mr. Butts. The Waynesburg quadrangle was mapped by R. W. Stone, assisted by M. I. Goldman. After the completion of the Waynesburg, Mr. Stone studied the Elders Ridge quadrangle, and was joined in the field mapping at the close of the season for three weeks by Mr. Woolsey and one week by Mr. Butts. Mr. Woolsey spent the season on the Beaver quadrangle, assisted during the latter part of the summer by Mr. Goldman. Mr. Campbell completed the Latrobe quadrangle and supervised the work of the other parties. In the progress of the topographic work in the Houtzdale quadrangle, A. C. Roberts made numerous notes on the geologic features, including the location of several faults, and prepared a preliminary areal geologic map.

Field Season 1903.—The Barnesboro and Patton quadrangles were mapped by Mr. Campbell, assisted by J. S. Burrows, F. G. Clapp and Geo. H. Ashley. Mr. Clapp and Mr. Ashley surveyed the Curwensville quadrangle during July and August. The Ebensburg quadrangle was studied by Mr. Butts, assisted by W. C. Phalen. Additional work was done upon the Beaver quadrangle by Mr. Clapp during May and June. Late in the season R. W. Stone completed the field work on the Elders Ridge quadrangle.

Field Season 1904. During the first part of the season, F. G. Clapp and F. W. DeWolf studied the Amity, and later, the Rogersville quadrangles. On October 20 Mr. Clapp began the study of the Houtzdale quadrangle, in which he was joined in November by Messrs. Ashley, Phalen and DeWolf. This year, for the first time, the method which W. T. Griswold had been using successfully in Ohio of taking fly-level notes on the geologic outcrops while leveling over the quadrangles for topography, was tried in Pennsylvania, the Burgettstown being so surveyed by Mr. Griswold and M. J. Munn.

Field Season 1905. The study of the Houtzdale quadrangle was continued by Geo. H. Ashley, David White and W. C. Phalen. Mr. White, who is the Survey's specialist on the Coal Measure fossils, accompanied Mr. Ashley over parts of the northeast corner of the Curwensville and northwest corner of the Houtzdale quadrangles and adjacent regions, to determine the age and presence of some of the lower formations. The fact that, so far as known, there are more faults in the Houtzdale quadrangle than in all the rest of the State of Pennsylvania west of the Allegheny Front, renders the tracing of the outcrops and the determination of the structure difficult and uncertain in this area. From May 1 to June 19 Edwin F. Lines was in the field collecting well records and locating wells on the Barnesboro. Patton, Amity, Rogersville, Claysville and Carnegie quadrangles. During July he made special study of the clay resources of the Kittanning and Rural Valley quadrangles. The geology and topography of the Claysville quadrangle was mapped by M. J. Munn, assisted by F. M. Hutchinson, and data collected for a bulletin on the gas and oil fields in the quadrangle. W. T. Griswold spent three months mapping the topography and began the study of the geology of the Clarion quadrangle, using the precise level methods of doing the geologic work which had been developed by him in Ohio. The Punxsutawney quadrangle was studied during August and September by G. H. Ashley, E. F. Lines and F. B. Peck. The geologic map of the New Castle quadrangle was begun by F. W. DeWolf, July 7 and completed about November 1. F. G. Clapp consulted with him on the glacial deposits for two weeks, and Mr. Ashley, on the general geology of the quadrangle for the same length of time. In December, R. W. Stone and F. W. DeWolf spent two weeks in Greene county in getting data needed to complete the geology for a bulletin on the oil and gas fields of that county.

Field Season 1906.—Geo. H. Girty spent six weeks during this season studying the relations of the Devonian and Carboniferous beds in New York and Pennsylvania. The survey of the Johnstown quadrangle was completed by W. C. Phalen, assisted by Lawrence Martin. The survey of the Clarion quadrangle was nearly completed by E. F. Lines, and M. J. Munn spent five months mapping the topography and geology of the Sewickley quadrangle. Additional work was done on the Punxsutawney, Curwensville and Houtzdale quadrangles by Mr. Ashley, and two weeks or less spent with each of the other field parties. Economic data was collected by F. B. Peck and R. W. Stone for a report on the mineral resources of Washington county. This work has since been suspended.

Field Season 1907.—G. H. Ashley did additional work on the Punxsutawney and Houtzdale quadrangles, and practically completed the same. He also visited the other field parties. E. F. Lines spent a month and a half completing the Clarion quadrangle. M. J. Munn spent three weeks on the Clarion, studying the oil and gas of that quadrangle; three weeks on the Claysville, completing work for folio publication, three weeks on the Sewickley quadrangle in preparation for both folio and an oil and gas bulletin, and the remainder of the season on the Carnegie quadrangle; and Chas. Butts began and completed the survey of the Warren quadrangle. The Carnegie quadrangle was surveyed by G. C. Martin, F. B. Peck and M. J. Munn.

PUBLICATIONS ON RESULTS OF RECENT CO-OPERATIVE SURVEY IN PENNSYLVANIA, AND OTHER PUBLICATIONS BY U. S. GEOLOGICAL SURVEY IN PENNSYLVANIA.

COAL.

Anthracite coal mining, by H. M. Chance. Mineral Resources U. S. for 1883 and 1884, 1885, pp. 104-131.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, pp. 212.

The stratigraphic succession of the fossil floras of the Pottsville formation in the southern anthracite coal field, Pennsylvania, by David White. Twentieth Ann. Rept., pt. 2, 1900, pp. 854-857.

An account of the occurrence of the Lykens coals in Stony Mountain and in the Dauphin basin.

The Pennsylvania anthracite coal field, by H. H. Stoek. Twenty-second Ann. Rept., pt. 3, 1902, pp. 55-117.

The bituminous coal field of Pennsylvania, by David White and M. R. Campbell. Twenty-second Ann. Rept., pt. 3, 1902, pp. 127-200.

Masontown-Uniontown folio, Pennsylvania, description by M. R. Campbell. Geologic Atlas U. S., folio 82, 1902, pp. 10-18.

Gaines folio, Pennsylvania, New York, description by M. L. Fuller. Geologic Atlas U. S., folio 92, 1903, p. 9.

Elkland-Tioga folio, Pennsylvania-New York, description by M. L. Fuller, W. C. Alden. Geologic Atlas U. S., folio 93, 1903.

Brownsville-Connellsville folio, Pennsylvania, description by M. R. Campbell. Geologic Atlas U. S., folio 94, 1903, pp. 11-17.

Recent work in the bituminous coal field of Pennsylvania, by M. R. Campbell. Bull. No. 213, 1903, pp. 270-275.

The Barnesboro-Patton coal field of central Pennsylvania, by J. S. Burrows. Bull. No. 225, 1904, pp. 295-310.

The Elders Ridge coal field, Pennsylvania, by R. W. Stone. Bull. No. 225, 1904, pp. 311-324.

Coal mining along the southeastern margin of the Wilmore basin, Cambria county, Pa., by Charles Butts. Bull. No. 225, 1904, pp. 325-329.

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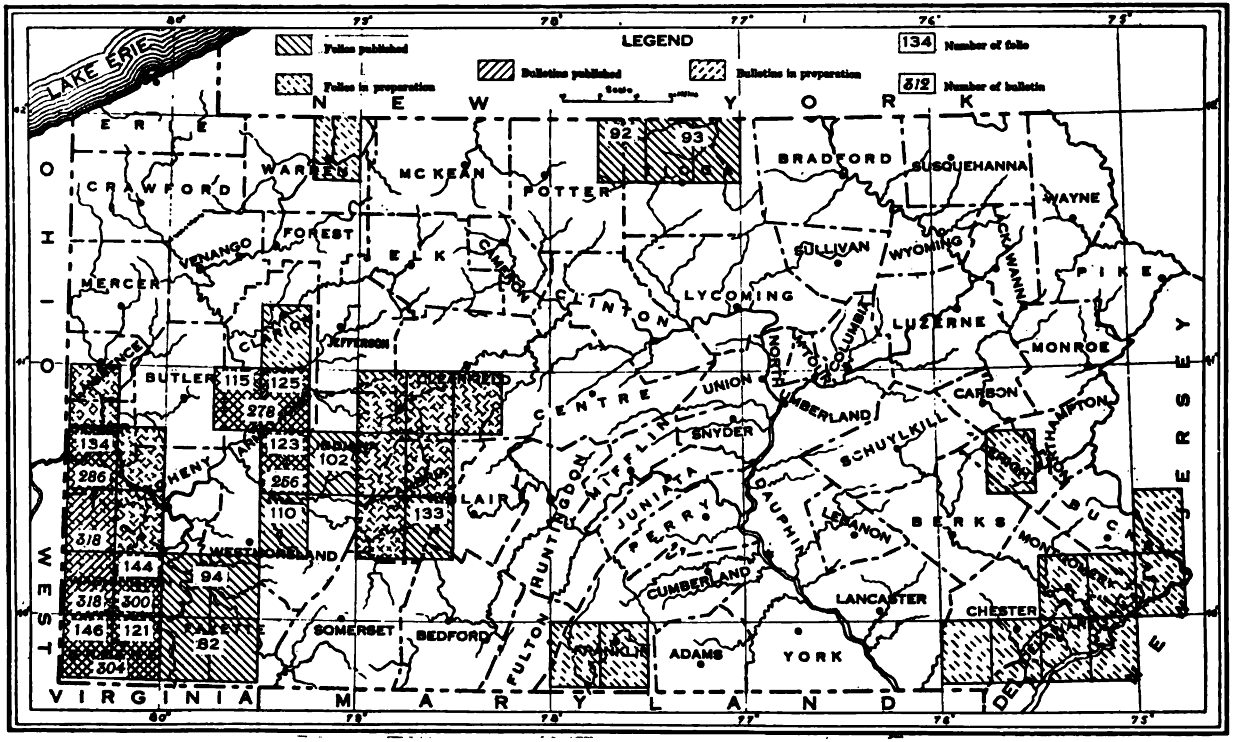

PLATE III. Key map showing covered by recent geologic work in Pennsylvania.

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METHODS OF GEOLOGICAL WORK.

At the present time two methods of field work are being used in Pennsylvania by the United States Geological Survey.

In the first, which is the method used all through the coal fields of the eastern and central States, the topographic map previously made is assumed to be approximately correct, and the position and elevation of outcropping rocks are determined from their recognized position on the map, the elevation being constantly checked by barometric readings from leveled points, or bench marks, or by the use of the hand level. By this method the elevation of any bed may be determined to within 20 feet, if the topographic map of the immediate neighborhood is correct within one-half that limit of error. As the older topographic maps are liable to have a greater limit of error at a distance from the lines leveled over, it has conservatively been assumed that elevations so obtained did not warrant the drawing of structure contours at closer than 50 feet. The essential feature of this method is that the area to be surveyed is covered with a close network of traverse lines along which notes are so taken as to form the basis of profiled geologic sections on which are shown all the observable outcrops, drillings, and other data to be obtained on or adjacent to each such line. These lines are run at not more than one mile apart and as much nearer together as may be necessary, and are supplemented by short side lines to mines, wells, observed or reported outcrops, or by lines which follow the outcrop, or the resulting debris of some selected stratum around the slope of the hill where it is necessary in order to make correlations between adjacent traverse lines. As the result of years of suggestions and criticisms, the methods of note-taking and recording observations have been systematized so that commonly from 10 to 25 miles or more of such traverses are run in one day by one man, when there are not involved mine examinations or a large amount of locating wells and other side work. On account of the large amount of time required in securing well records and in locating them, examination of mines and the study and copying of mine maps, and other work of that nature, the average for any season will of course be much lower.

Since the beginning of the work in Pennsylvania there has been a steady tendency to raise its character in two ways—first, in giving more attention to the purely economic side of the work, such as the workability of the coal beds, the existence, position and character of economic deposits of clays, sandstones, limestones, et cetera. This side of the work has increased to such an extent that recently it has been found desirable to prepare economic bulletins on the areas surveyed to prevent overbalancing in the folios. The economic bulletins will have the added advantage in the future of quick publication, and convenient form for use in the field or office. The second tendency has been increased accuracy in the determination of the geology. This is in part possible through the constant raising of the grade of the topographic maps used as a base and in part attained by the more frequent use of the hand level in place of the barometer.

In certain areas an entirely different method of work has been introduced. In these areas the following factors exist:

(1) There are oil and gas deposits, or coal beds of large economic importance; (2) the strata maintain very constant thickness; (3) the strata have characteristics by which they may generally be recognized at sight when their approximate stratigraphic position is known; (4) where the dips are usually slight, and (5) where outcrops are abundant and clean. This method consists in combining the geologic and topographic work to the extent of having men of some geologic training run the fly levels when that stage of the topographic work is reached, making and recording at the same time observations on the geology. In running these levels they make note of the elevation of all outcropping rocks, particularly those of workable coals, or of limestones and other rocks of which the stratigraphic position is known. They also run instrumentally additional side lines to the top of any well of which the record has been or it is hoped will be obtained, to the mouths of the mines, et cetera.

The advantages of this method of work are that, under the proper conditions, as stated above, it permits of mapping the outcrops of coals, clays or other economic beds as accurately as the present scale of the Pennsylvania maps, 1 mile to the inch, will permit of showing; and, second, it makes possible the showing of the structure or lay of any given bed, that is, its elevation at any point, whether exposed or hidden, to within a limit of error well within 10 feet. In determining the structure of oil or gas-bearing rocks, where the dips are slight, as over much of the western part of Pennsylvania, western West Virginia, or eastern Ohio, this slight gain in accuracy may greatly affect the value of the resulting information, enough so as to be worth many times the added cost. It is undoubtedly the cheapest method of obtaining leveled elevations on geologic features yet devised. In addition to these direct economic results, this strictly accurate work is leading to the solution of certain theoretic questions which will have the highest future value. In the first place, this work combined with the steel tape measurement of oil and gas wells, is yielding a mass of exact data such as has never before been possessed, and which now seems likely to throw a flood of light on the relation of the oil and gas accumluation to the structure of the rocks. It allows the determination of the structure of some outcropping rock with great accuracy, and then by combining the instrumentally determined elevations of the top of the wells with the steel-tape measurements to the oil-bearing sand, it is possible to obtain the structure of that sand with an accuracy never before attempted on a large enough scale to throw light on the broad problems involved. Already the fact that the oil sands often have quite a different structure from that of the rocks outcropping at the surface has not only been amply demonstrated, but methods of determining the divergence have been worked out. Its regularity or lack of regularity has been studied, and plans devised for properly projecting the surface structure down to the level of the oil-bearing sand, at the same time allowing for the varying change of interval between the two planes. With the structure of the oil-bearing sand thus accurately determined, it is confidently hoped that, with the accumulation of data, it will be possible to perceive and demonstrate the exact relation of the accumulation of the oil and gas to the structure of the rock stratum containing them. When this has once been done, the laws so derived will be of incalculable value in the locating of future drilling, and may be applied by any engineer.

A second theoretic result of future economic value has been to show, as far as the work has yet been carried on, that in the area of one quadrangle the greatest variation of interval between certain well-recognized members of the upper Conemaugh or Monongahela formations is under 20 feet, and that the average of the intervals between these members in the townships of a single quadrangle is within 3 feet. In 1906 this method of work was undertaken for the first time in areas where the outcropping rocks belong in the Allegheny formation or Lower Productive Measures. It is certainly hoped that new light will be thrown on the question of the persistency of the intervals between the various members of the Allegheny. Already it appears probable that it will demonstrate the relative persistence of certain intervals as between the Upper Freeport or "E" coal, and the Lower Kittanning, or "B" coal, and the lack of persistency of some of the other intervals. It may lead the way to an understanding of the stratigraphy of the Allegheny formation that may be of eminent value in future attempts to trace or develop the coal and other members.

That it is an ideal method of obtaining geologic data for preparing geologic maps of the highest grade of accuracy is evident. The objection is the cost. The running of fly levels requires two men and is necessarily a slow operation, the party covering only about one-fifth as much territory in a day as the single geologist by the first method. So that, notwithstanding that such portion of the expense as it would have cost to run the fly levels alone is met from the funds from topography, yet the fact that the traverseman must be a trained geologist, or at least a trained observer, backed up by a trained geologist, renders the method expensive. To make it worth while aside from the theoretic value obtained, this method must be restricted to regions where the oil and gas or coal are of large economic value, and where the conditions, as previously stated, permit of doing work which over the larger part of the area surveyed will have a limit of error or less than 20 feet. The cost of the field work for the geology is about $8.00 per square mile. When it is considered that private engineers now using the same methods practically as those used for the Federal Survey keep constantly busy charging at least $100 per square mile, it is evident that the cost is but a small fraction of that warranted by the economic values of the land where the proper conditions exist. It has already been demonstrated that these conditions do exist over a large area in western Pennsylvania and adjacent regions in West Virginia and Ohio. It is the policy of the Federal Survey not to undertake work of this expensive nature except in co-operating States where the State will share in the expense.

REVIEW OF GENERAL GEOLOGY. PREPARED BY RALPH W. STONE.

PHYSIOGRAPHIC AND GEOLOGIC PROVINCES.

The State of Pennsylvania is entirely within the Appalachian Province. The Coastal Plain extends only to the Delaware River from Trenton to Philadelphia and thence southwest to Baltimore, while the Appalachian Province extends from the western border of the Coastal Province to the Mississippi lowlands. Therefore, practically the entire State, excepting possibly a few square miles south of Philadelphia, is in the Appalachian Province.

COASTAL PROVINCE.

The Coastal Province borders the entire eastern part of the North American continent, and has a nearly uniform width of 250 miles. It is divided into two parts by the present shore line—a submerged portion known as the continental shelf, and a subaerial portion commonly called the Coastal Plain.

Continental Shelf. The eastern half of the Coastal Province, the continental shelf, extends from the present shore line to a well-defined escarpment from 5,000 to 10,000 feet high, which generally begins at a depth of 450 to 500 feet below sea level, and which is found at a distance varying from only a few miles to 300 miles off the coast. This continental shelf is very narrow on the east coast of Florida, widens to 150 miles off the coast of Georgia, about 100 miles off the coast of New York, and 300 miles off the coast of Newfoundland. The sea bottom which this shelf forms has a very regular surface sloping gently toward the escarpment and marked only by the deep-sea channels of old river valleys. Some of these channels have been traced by soundings from the present shore line to the edge of the continental shelf. The channel opposite the mouth of the Hudson is particularly well marked and has been traced to the edge of the shelf 100 miles east of New York City.

Coastal Plain. The Coastal Plain, which is the subaerial portion of the Coastal Province, also varies considerably in width, but the combined width of the Coastal Plain and the continental shelf is approximately 250 miles. The Coastal Plain seldom reaches 400 feet in elevation, and is, for the most part, less than half that height. From its western boundary, marked by the falls in the larger streams, it slopes gradually southeastward. The relief throughout most of the plain necessarily is inconsiderable. Throughout the greater part of the area the streams flow in open valleys at a level only slighter lower than that of the broad, flat divides. Bays and estuaries are numerous and represent the submerged valleys of streams carved when the belt stood at a higher level.

The western limit of the Coastal Province is a well-marked physiographic feature. Where the rivers flow from the narrow valleys of the eastern edge of the Piedmont Plateau out onto the lower level of the Coastal Plain, they are interrupted by falls which mark the head of navigation. The falls are on the eastern line of outcrop of the crystalline rocks which underlie the Piedmont Plateau. These falls marking the western limit of the Coastal Plain are found in the Delaware River at Trenton, in the Schuylkill at Philadelphia, in Jones Creek at Baltimore, and in the Potomac at Washington.

APPALACHIAN PROVINCE.

The Appalachian Province extends from the line of falls in the large streams described as marking the boundary of the Coastal Plain westward to the Mississippi lowlands and from Canada to

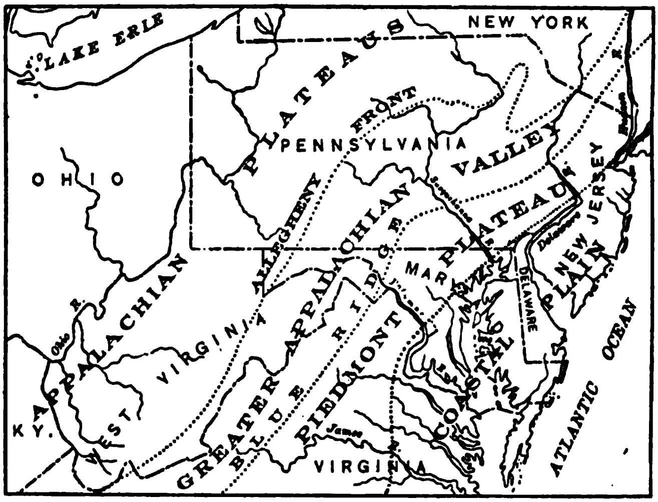

FIG. 1.—Diagram of northern portion of the Appalachian province, showing physiographic divisions.

Alabama. As above stated, practically all of Pennsylvania lies in this Province. The Appalachian Province in Pennsylvania is divided into two nearly equal parts by a line which follows the Allegheny Front across the State. East of this line are the Greater Appalachian Valley, and the Appalachian Mountains and Piedmont Plateau, and west of it, the Appalachian Plateau, formerly called the Allegheny Plateaus. The Greater Appalachian Valley comprises in Pennsylvania a succession of valleys, narrow ridges constituting the central district, while the eastern division of the Province embraces the Appalachian Mountains, which border the Greater Valley and the upland to the east, known as the Piedmont Plateau. The divisions of the Appalachian Province are shown in the accompanying figure.

Piedmont Plateau. The Piedmont Plateau extends from the Coastal Plain to the eastern foot of the Appalachian Mountains. On the northeast it merges into the New England Plateau, and on the southwest, curving with the coast, extends into Alabama. This upland has a mean width of 60 miles and a maximum, in the central portion, of 120 miles. The Piedmont Plateau in Pennsylvania is a diversified upland of moderate elevation dissected by rather shallow, open valleys, which become narrower and more deeply incised on the eastern margin. In Pennsylvania the plateau descends from an elevation of 900 feet to an average of 200 feet near Philadelphia. Above it rise occasional hills which erosion has not reduced to the level of the plain. Long Hill and Gibraltar are examples of monadnocks rising 100 to 200 feet above the Piedmont Plateau in Pennsylvania. Rock Ridge and State Ridge are similar monadnocks on the upland in Maryland. The western limit of the plateau is marked by the Highlands of New York and New Jersey, by Musconetcong, Lehigh and Neversink Mountains, South Mountain and Blue Ridge.

The Greater Appalachian Valley. All the country between South Mountain and Blue Ridge on the east and the Allegheny Front on the west is embraced in the Greater Appalachian Valley. It is divisible longitudinally into the Greater Valley on the east and the belt of Allegheny Ridges on the west. The Greater Valley is known as Shenandoah Valley in Virginia, Hagerstown Valley in Maryland, and Cumberland Valley in Pennsylvania.

The zone of Allegheny Ridges occupies the greater part of the Greater Appalachian Valley. The distinctive features of the topography of this zone are long, parallel, sharp-crested ridges and narrow intervening valleys. These cross the State from northeast to southwest. Minor ridges subdivide the valleys lying between major elevations. The major ridges are characterized by long, even, almost uninterrupted crest lines and by uniform and but slightly dissected slopes. Marked parallelism between the ridges is a striking feature.

Cross profiles of the ridges are commonly very expressive of the internal structure or attitude of the rocks which make them. Some of the ridges are due to the arching up of resistant strata, such as hard, massive sandstone and quartzite. In such case either slope has its steepness controlled by the inclination of that resistant stratum. Monoclinal ridges in which all the beds dip in the same direction are steep on one side and on the other conform to the dip of the controlling stratum. A synclinal ridge which is a common form in this region has a trough-like internal structure or arrangement of the beds. The bed of resistant rock forms the crest of the ridge and protects the underlying softer rock which have been worn away around the edges of the ridge.

The area of the higher ridges is less than that of the valleys. The average elevation of the valleys in the Greater Appalachian Valley is lower than the mean elevation of the plateau region on the west. All the larger valleys are determined in position and direction by the arrangement of the more yielding rocks. They have been developed subsequent to the deformation of the strata and are not consequent upon the original troughs and ridges.

The courses of the smaller streams are generally parallel with the structure. The larger streams however do not adhere strictly to this general rule but, after flowing parallel with a larger ridge for some distance, turn abruptly and cut through the ridge in a narrow V-shaped gorge, after which they may again resume the parallel course.

The Appalachian Plateau. (Formerly Called the Allegheny Plateaus.) The westernmost division of the Appalachian Province extends from the Allegheny Front westward to the Mississippi lowlands and hence includes all the western and northern part of the State of Pennsylvania. As the old name—Allegheny Plateaus—implies the surface of this division of the Province is composed of a number of plateaus. The highest and most extensive lies along the southeastern margin of the division, and extends from Alabama to New York. Its altitude is about 2,800 feet on the southern line of Pennsylvania and 2,300 to 2,400 feet in the central part of the State. The plateau is widely developed in the northern counties of Pennsylvania and throughout southern New York, where in ranges in altitude from 2,000 to 2,400 feet.

In Pennsylvania this old plateau, known as the Schooley peneplain, is generally so dissected that only the hilltops mark its former position. It is tentatively correlated with the Cumberland Plateau. The next younger and lower plateau which is recognized in Pennsylvania is the Harrisburg peneplain. It has an altitude of 1,200 to 1,300 feet in southwestern Pennsylvania and about 2,000 feet in the northern part of the State. In the central and northern part of the State these two plateaus seem to approach each other and the separating escarpment becomes lost in a maze of irregular hills.

Both of these plateaus, which are believed to have reached the stage in peneplanation where the surface is that of a plain across which the rivers flow in broad, shallow valleys, are now so dissected as to be recognizable only by a broad view from a position at or just above their general level. That this deeply dissected region once was a plain is suggested by the general accordance in elevation of the hill and ridge summits. The whole western part of the State which is included in the area of the Allegheny Plateaus is now a monotonously hilly country. The drainage system is a fine network which has broken up the old plains into a mass of irregular ridges having no common trend or systematic arrangement, and the valleys commonly are narrow and several hundred feet lower than the crests of the intervening ridges.

GEOLOGY OF THE PROVINCES.

COASTAL PROVINCE.

The hard rocks underlying the Coastal Province at an unknown depth are concealed by unconsolidated deposits of gravel, sand and clay, which were laid down in a marine estuary and along the former coast line during Cretaceous time. Nothing is known about these deposits on the continental shelf or that part of the Coastal Province which is east of the present shore line and submerged, but where exposed on the Coastal Plain they are the Patapsco and Raritan formations of the Lower Cretaceous, and Magothy, Matawan, Monmouth and Rancocas of the Upper Cretaceous. Overlying these is a thin covering of sand and gravel deposited during Tertiary and Pleistocene times. They show that the Coastal Province was submerged beneath estuarine water during these periods.

APPALACHIAN PROVINCE.

Piedmont Plateau. The even slope of the Piedmont Plateau is due to long-continued erosion, and not to rock structure, for the underlying rocks are highly complex. They include greatly metamorphosed crystalline material, and unmetamorphosed fragmental material. The oldest formation of the Pennsylvania Piedmont is presumably of igneous origin, consolidated from the molten condition. Since consolidation it has been subjected to pressure and metamorphism, which have produced an obscurely banded structure. Gneiss, then, forms part of the composite floor of the Piedmont. Later formations, chiefly of sedimentary origin, were accumulated beneath the sea which covered this part of the globe, and were consolidated by pressure and cementing material. Subsequently they have been uplifted and folded.

The first of the sediments deposited in this interior gulf were arkosic and argillaceous and were deposited in pre-Paleozoic time. Subsequent compression and folding developed from them hard, crystalline, finely-banded quartz-feldspar gneiss, and a mica-gneiss. The former is intimately associated with the more massive gneiss described above and with it forms the composite Baltimore gneiss, while the latter is known as the Wissahickon mica-gneiss.

The pre-Cambrian orogenic movements which changed the sediments to gneiss were accompanied by the intrusion of bosses, sills and dikes of molten matter, which altered the sediments and which consolidated as granite, gabbro, pyroxenite and peridotite.

At the beginning of Paleozoic time a narrow strait of water lay between Appalachia and the land on the west. Into this sea were brought the sediments which formed the sedimentary rocks of the Appalachian Province. The deposition on the gneiss was successively sands, sands and clay, limes, and lastly, clays. The lower part is chiefly of mechanical origin and 3,000 feet thick, while the upper part is organic or chemical, and in Pennsylvania 6,000 feet thick. These rocks, deposited in Cambrian and Ordovician time, extend over a considerable portion, but not all, of the Piedmont. During this period the lands were eroded to low relief and the waters of the narrow straight widened to an inland sea which spread eastward, perhaps beyond the present coast, and westward to beyond the Mississippi. The formation of limestone, due to chemical precipitation or to microscopic organisms, continued from the Ordovician over into Lower Silurian time. Folding and faulting changed the character of these rocks, and they are now the Chickies quartzite, Shenandoah limestone and Octoraro mica-schist. These crystallized sediments and igneous intrusions constitute the foundation of the Pennsylvania Piedmont Plateau, but are uncovered only in detached belts trending northeast and southwest.

In a shallow inland estuary which covered the central and northeast portion of this eroded crystalline floor of the Piedmont coarse and fine sands and mud accumulated in the Triassic period. Contemporaneously igneous material was intruded between the beds of sediment, or traversed fissures in them, or was poured out as lava flows. These sediments were consolidated and uplifted without being metamorphosed. In Pennsylvania and New Jersey they are known as the Stockton and Lockatong sandstones and Brunswick shale. The contemporary igneous intrusives are diabese and basalt. These latter resist erosion and form ridges, such as the Palisades in New

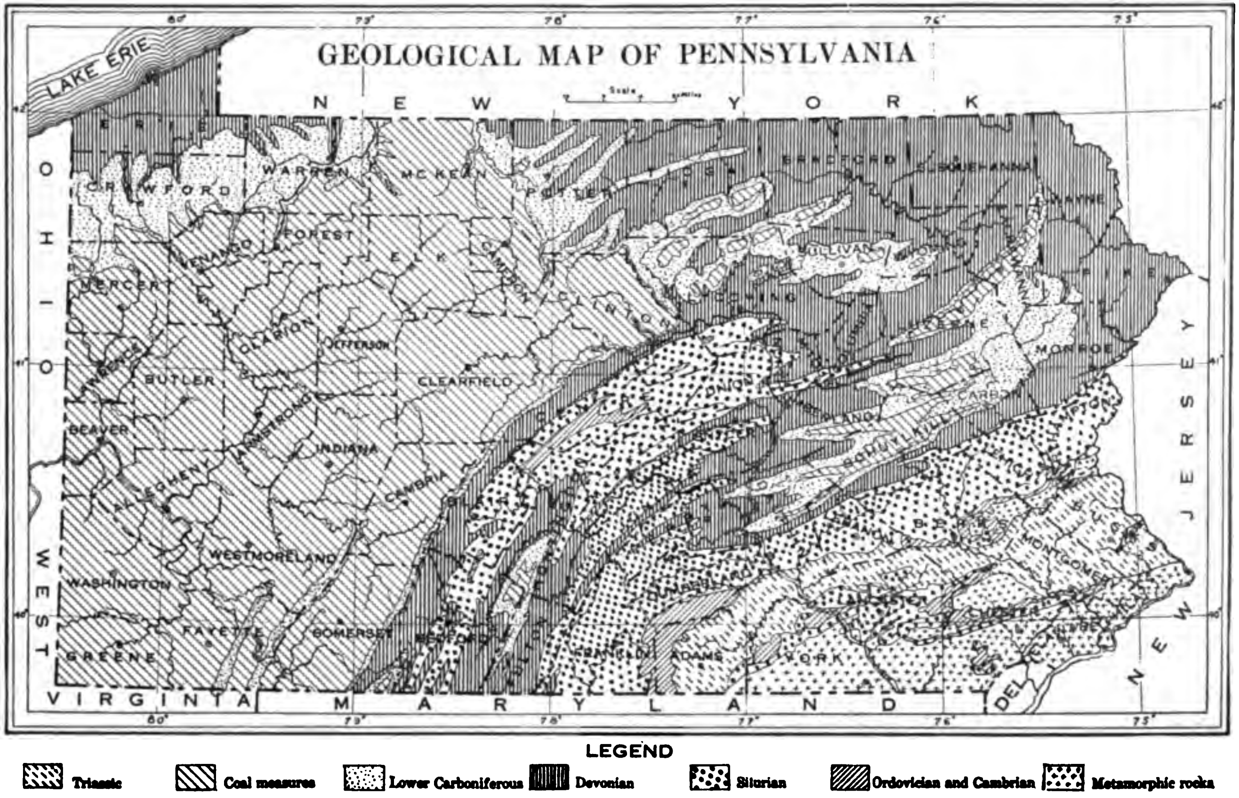

Plate V. Geologic Map of Pennsylvania.

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York and New Jersey, the First and Second Watching Mountains and Sourland Mountain in New Jersey, Haycock Mountain, Rock Hill, Long Hill, Gibraltar Hill, and many other lesser eminences in Pennsylvania.

The Cretaceous sediments which are so abundant on the Coastal Plain and which consist of unconsolidated gravel, sand and clay, lap over upon the eastern border of the Pennsylvania Piedmont and conceal the underlying crystalline floor. In scattered areas there are remnants of sands and gravels belonging to the Tertiary and Pleistocene periods. They show that while the Coastal Plain was more or less continuously under water from Cretaceous to Pleistocene time, the Piedmont Plateau was intermittently submerged beneath estuarine waters during these periods.

The same geologic structures and formations appear also in the Appalachian Mountains. Topographically the change is abrupt from trenched upland to flat-topped mountains and ridges. Yet the mountains and plateau express the same history.

GREATER APPALACHIAN VALLEY AND APPALACHIAN PLATEAUS.

Paleozoic Era. In the valleys and narrow ridges of the Greater Appalachian Valley the Silurian and Devonian rocks are prominently exposed. Farther west they are deeply buried under the Appalachian Plateaus. The sediments forming these rocks were deposited in a narrow trough. The Lower Silurian limestone mentioned above was followed by 3,000 to 4,000 feet of shale and sandy shale, indicating moderately slow erosion of the land and rivers removing their flood plains. The rise of Appalachia, or the old land on the east, until the coast reached the position of the present mountains, was accompanied by downbending along the present Appalachian Valley. With the deepening of the sea at one place came the rise of the bottom in another. The sea floor rose above water, making a land area known from its location and structure as the "Cincinnati Arch." Between this new land and Appalachia on the east was a trough in which same waters loaded with mud and sand. The red color of the sediment indicates the deeply oxidized condition of the land from which they came. As the sea deepened shale and limestone were deposited and were followed by white sandstone. After the deposition of a considerable amount of white sandstone in the lower part of the Silurian, rising land in New York barred off the St. Lawrence drainage and caused a return of ferruginous conditions giving gray, red and olive-green shale and sandstone which vary from 2.600 feet thick in Pennsylvania to 1.000 feet elsewhere. The slight variations in level during the deposition of these beds caused accumulation of limestone and salt at different horizons. The Silurian period closed with deposition of the Oriskany sandstone, which was deposited off a westward-advancing coast.

At the beginning of the Devonian period the Oriskany sand-stone, which had been raised above sea level, was subjected to slight erosion, and on it a rich coral fauna built up the Corniferous limestone. That the surrounding land areas were low-lying, morass-like and covered with vegetation, is indicated by the next deposit, which is a black shale of remarkably uniform character, and extreme regularity of occurrence throughout a considerable area. This shale, which is from 1,400 to 1,500 feet thick in Maryland and 1,200 feet thick in New York, thins out to a feather edge in northern Arkansas and Alabama. It seems to be a roughly, oval-shaped deposit many hundred miles in extent, with a considerable thickness along the eastern margin, but thinning gradually toward the west and south. That the sea in which this black shale was deposited continued to deepen is shown by the succeeding formations, which consist of sandy shale and shaly sandstone having a maximum thickness of 10,000 feet in Schuylkill county, Pennsylvania. The sediments seem to be mostly those of shallow water, but the great thickness and recurrence of similar conditions suggest a fluctuating, but continual, deepening sea. These beds were prevailingly red. Following their deposition fresh-water conditions probably prevailed throughout the northern end of the Appalachian Gulf, but the character of the material brought a change from red to gray and from clayey to sandy. The record of this period, the Lower Carboniferous, is found in the Pocono formation represented largely by the "Big Injun" sandstone. As the deposition of this coarse, sandy material was drawing to a close a large quantity of carbonate of lime was deposited with the sand, making what is known in Pennsylvania as the Loyalhanna or "siliceous limestone." Another change in the relation of the lands to the sea brought about a return of conditions similar to those in the Devonian, and the limestone was covered by a deposit of red sediments now known as the Mauch Chunk formation. The great mass of this formation is red shale, which in eastern Pennsylvania reaches a thickness of over 2,000 feet, a fact which indicates continuous subsidence along the axis of the Appalachian Gulf. The thickness of this formation decreases westward. On the Allegheny Front, west of Altoona, it is 180 feet, while in Armstrong county and further west the Mauch Chunk is absent. This varying thickness points to an uplift that raised above water a large land area extending from southern New York to western central Pennsylvania, and as far east, probably, as the Allegheny Front. From the western part of this area the Mauch Chunk, and possibly the upper part of the Pocono were eroded before the deposition of the overlying Pottsville. The great variation in the thickness of the Pottsville, according to inferences reached by David White through the study of fossil plants, is ascribed to the fact that at about the beginning of the Pottsville epoch an uplift occurred which affected much of the Ohio Valley. A large land area was formed that extended as far east as the Broad Top and Northern Anthracite fields. This land was persistent until at least 600 feet of Pottsville sediments were deposited in the Southern Anthracite Basin, and it may have been during this time that the Mauch Chunk was eroded. The subsidence, then, occurred continuously until unbroken sedimentation was resumed from the anthracite basins to the westward edge of the bituminous field. Thenceforth oscillations of the sea floor exposed it to long periods of at least partial emergence. Such periods are marked by coal deposits. Thus, the coal beds in the Pottsville represent times when the surface was low and marshy and a luxuriant vegetation grew upon it, while the heavy, cross-bedded sandstones or conglomerates represent periods of submergence. Following the Pottsville epoch, periods of emergence, when plant life thrived, became more and more frequent, and the sequence of sandstones, shales, limestones and coal beds, known as the Allegheny formation, were deposited. The geologic history recorded in the sediments of the Allegheny formation tells of a series of rapidly alternating conditions frequently repeating themselves. Each group of events began by the deposition of many feet of shale and sandstone, probably in a shallow sea near the shore. Then, either because of an arid climate or the migration of the shore line, sedimentation of mud and sand ceased, and in the resulting clear waters carbonate of lime was deposited. After this period of quiescence elevation brought the sea bottom to the surface and luxuriant plant life thrived upon the low-lying land. The deposition of the vegetable matter which subsequently formed the coal beds closed each of the frequently repeated periods in the Allegheny. A similar series of events, but lacking in emergence and consequent development of a heavy growth of vegetation, is represented in the rocks known as the Conemaugh formation. That limited areas supported plant life for a short time is shown by coal beds of small extent and thickness, and that marine conditions prevailed at times in the Appalachian Gulf is evidenced by the salt water fossils of the Brush Creek and Ames limestones. The Ames limestone marks the last return to marine conditions in the Appalachian Basin. Submergence, therefore, prevailed throughout this region, but land areas somewhere stood long exposed to subaerial weathering, for beds of red shale occur in the formation.

With the advent of Monongahela time begins a succession of events similar to those recorded in Allegheny time. The great period of coal formation, whose widespread and long-continued conditions are shown by the extent and thickness of the Pittsburg bed, marks the initiation of these events. Submergence of the great and widespread mass of vegetation was accompanied and followed by a heavy deposition of sand, and subsequently several hundred feet of strata that included coal beds representing periods of emergence, were deposited until the Appalachian Sea was finally filled, and the shore in eastern Pennsylvania migrated westward.

Plant growth that formed the Waynesburg coal was followed by another submergence, which closed the Monongahela epoch. An accumulation of similar sediments followed, indicating practically a repetition of the Monongahela conditions, except that the periods of emergence and development of extensive marshes covered with vegetation were of shorter duration. That the change from land conditions to deep water in some instances was rapid is suggested by the fact that the Lower Washington limestone, which indicates clear, and possibly, deep water, lies directly on top of the Washington coal. This series of rather barren measures above the Waynesburg coal known as the Dunkard Group seems to indicate in its lower part a general deepening of the whole basin. Sedimentation seems to have continued until the Appalachian Gulf was completely filled. The rocks in the deeper portions aggregate an unknown thickness, probably hundreds of feet more than the thickest sediments now remaining in the hills of southwestern Pennsylvania. With them ended the Paleozoic deposition in this part of the world.

Appalachian Revolution. The close of the Dunkard epoch marks not only the end of sedimentation but also the beginning of a long-continued series of events of an entirely different nature. From the beginning of deposition in the interior sea subsidence had been going on intermittently and sediments had been deposited until thousands of feet of strata had accumulated. From the close of the Carboniferous period until the present time the reverse movement—elevation—has prevailed in this region, which has been continuously a land area since the close of the Dunkard epoch.

This change from subsidence to elevation known as the Appalachian Revolution was produced by compressive stresses, which resulted in warping the rocks into great folds. The movement was most severe along the eastern side of the Greater Appalachian Valley, where the rocks were not only closely folded but in many cases metamorphosed. In the Allegheny Plateaus the disturbance was less severe and the rocks were warped into broad, comparatively low, folds. In a measure, the Appalachian coal basin seems to have acted as a bulwark against which the stress coming from the east crushed the rocks of the Piedmont Plateau and Greater Valley. The folding continued across the basin, but with greatly decreased effect.

Mesozoic Era. As the new land surface rose gradually out of the interior sea, owing to the compressive forces, erosion commenced, and the streams began to carve valleys and carry away the sediments which had been deposited during Paleozoic time. This erosion has been going on continuously ever since. Before the close of the Cretaceous period the Appalachian Province was worn down to a nearly horizontal plain known as the Schooley peneplain. Subsequently this peneplain was elevated to a height of 800 feet or more above the sea, and its destruction began at once. The harder rocks on the greater folds, like Chestnut Ridge, were left in relief, while the softer rocks were again reduced to a fairly even surface called the Harrisburg peneplain, which has been referred to early Tertiary time. It too, was elevated, and subsequently eroded. That it was raised unevenly is shown by the fact that in the northern part of the State it is 400 to 700 feet higher than in the southern part. Subsequent elevation and periods of quiessence have produced wide valley floors, which in their turn have been incised by renewed elevation of the land, and left as terraces above the present flood plains.

During glacial times the great continental ice sheet advanced repeatedly into northern Pennsylvania and left in its wake deposits of sand and gravel of considerable extent, which mask the underlying formations. During this period some of the rivers were overloaded with detritus, filled their valleys, and changed their courses. Since that time they have, in some cases, cut through or below the glacial material. The only deposition of post-Glacial time is the alluvium forming the modern flood plains, which is deposited by the streams as they overflow their banks from time to time.

REVIEW OF GENERAL GEOLOGY OF SOUTHWESTERN PENNSYLVANIA IN LIGHT OF RECENT WORK.

PHYSIOGRAPHY OF SOUTHWESTERN PENNSYLVANIA, BY RALPH W. STONE.

The topographic mapping of a considerable portion of southwestern Pennsylvania has made possible a study of certain physiographic problems of such a broad character that they could not be well undertaken previous to the preparation of such maps. They afford an opportunity for the study in the office of the more pronounced features and aid greatly in the correlation of field observations. By the use of these maps it has been possible to confirm certain ideas that have been developed concerning the physiographic changes which have taken place in this State.

Schooley Peneplain. One of the problems which came to the attention of the geologists working in western Pennsylvania in recent years was the evidence of the former existence of peneplains. Study of this subject shows that with the emergence of dry land, which was the result of the Appalachian revolution, or uplift, degredation began, and when the orogenic forces gradually died out the elevation of the province ceased. During the long period of quiessence which ensued, it is probable that the surface of the Appalachian Province was eroded approximately to a horizontal plain near sea level. This is called the Schooley peneplain. It is believed that it was completed before the end of Cretaceous time. The level crests of many of the ridges of the Greater Appalachian Valley, of which those just east of the Allegheny Front, in Blair county, are good examples, may approximately represent the surface of the Schooley peneplain. The remnants are so few, however, that it will not be further discussed.

Harrisburg Peneplain. After the production of the above-mentioned plain an uplift occurred and erosion once more became active. With the cessation of the uplift a sufficient time elapsed to develop another peneplain which became so extensive as to almost obliterate the one previously formed. This is called the Harrisburg peneplain and is believed to have been developed in early Tertiary time. The length of time necessary for the growth of such a plain is inconceivable, but the evidence is clear that such a plain was developed. Throughout all of western Pennsylvania its effect upon the topography of the present is marked. The general accordance in elevation of hill summits or of uplands suggests to the observer that the

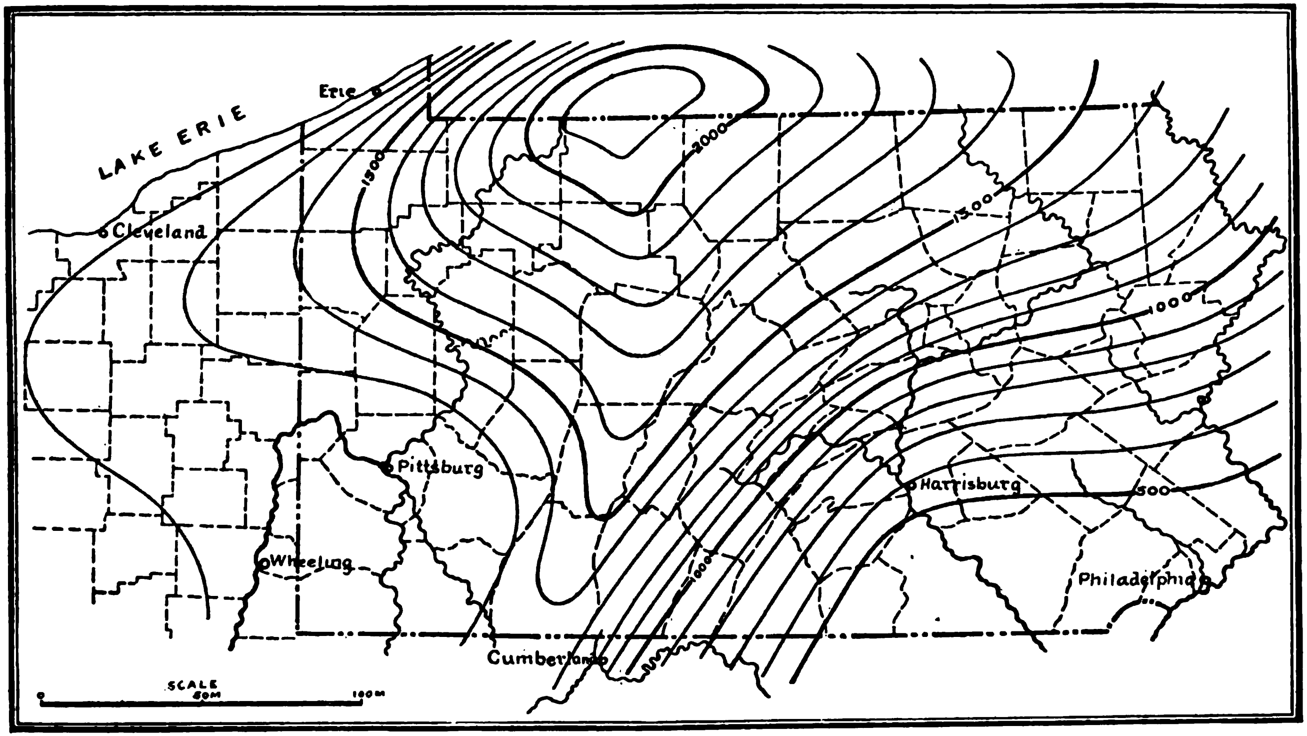

Plate IV. Map showing warped Surface of Harrisburg (Early Tertiary) Peneplain. Contour interval, 100 feet.

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country, which is now completely dissected, must have once been a broad plain into which subsequent elevation has caused the streams to cut their present valleys. The development of the Harrisburg peneplain was arrested by an uplift of unequaled intensity. In southwestern Pennsylvania it seems to have been slight, but in the northern part of the State it amounted to several hundred feet, as is indicated by the fact that the present level of the remnants of this peneplain is 2,100 feet in southern New York, over 1,400 feet in Armstrong county, and 1,250 feet in the southern part of this State. The deformation is ellipsoidal, or dome-shaped about a general center located in Potter or McKean county, where its surface reaches an altitude of about 2,200 feet above sea level. From this point of greatest elevation the slope is continuous and gradual to the vicinity of Harrisburg, where the elevation is a little over 500 feet. The discussion of a physiographic feature of this sort necessitates a consideration of many details and can not further be considered in this brief paper. For a longer account, reference should be made to paper* by M. R. Campbell, entitled "Geographic Development in Northern Pennsylvania and Southern New York."

Later Developments of Terraces. As the elevation which warped the Harrisburg peneplain proceeded the streams renewed their activity and the former flat surface was soon furrowed by valleys. When the land had risen about 100 feet above its former position the upward movement seems to have halted and the development of another plain began. This stage in the physiographic development of the State is known as the Worthington peneplain, and probably occurred in the latter part of Tertiary time. It was by no means so extensive in its development as either of the older peneplains. Later uplifts and periods of quiessence resulted in the further destruction of the previously formed plains by the renewed deepening of the valleys. These stages are shown by the steep bluffs and the terraces, or rock-cut benches found along the sides of the main streams. These benches represent the periods when uplift ceased and the streams had opportunity to widen their valley floors, and the bluffs represent periods of elevation. These later benches are known as "straths," the oldest one next succeeding the development of the Worthington peneplain being called the Parker strath. This probably marked the close of Tertiary time, for its further development was arrested by the events of the Glacial period. The relation of these straths and the present flood plains to the Worthington peneplain in Armstrong county is illustrated diagrammatically in the accompanying figure.

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*Bull. Geol. Soc. Amer., vol. 14, pp. 277-296. 1903.

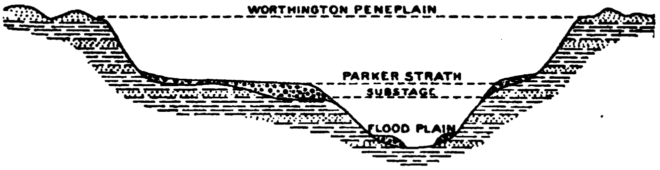

Fig. 2. Ideal section across Allegheny Valley illustrating the relation of terrace floors.

Along some of the larger streams still later stages are recognized which were developed in inter-glacial times. The relation of these later sub-stages to the older straths and peneplains are shown in the figure which follows.

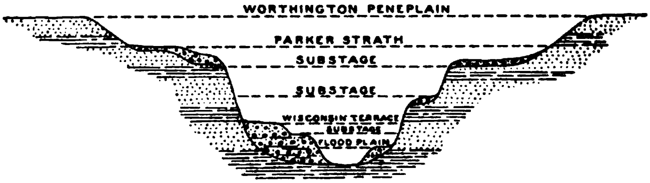

Fig. 3. Generalized section across the Ohio Valley showing terraces.

For a description of the development of these peneplains and straths in western Pennsylvania reference should be made to the folios describing the geology of quadrangles in western Pennsylvania.

Drainage Diversion. A notable feature of the drainage system of western Pennsylvania is the fact that a number of the main streams head within a few miles of Lake Erie, and flowing south, join the Ohio drainage. The Beaver river has its source on the northern slope of a region which would naturally drain into Lake Erie. Its headwaters, in fact, are only a score of miles distant from the lake, but they lead directly away from it, and the same is generally true of the Allegheny river. It may be noticed further that the valleys of Beaver river and Ohio river above Beaver form a nearly straight line, and that from this line the Ohio below Beaver takes an almost right angle turn to the west. This unusual relation of the main to the lateral stream was recognized many years ago, and detailed work along the Beaver Valley reveals the fact that the rock floor of the high terraces slopes northward. In view of these facts, it is concluded that the Ohio once flowed northward into Lake Erie through the Beaver Valley, as is illustrated in the accompanying figure.

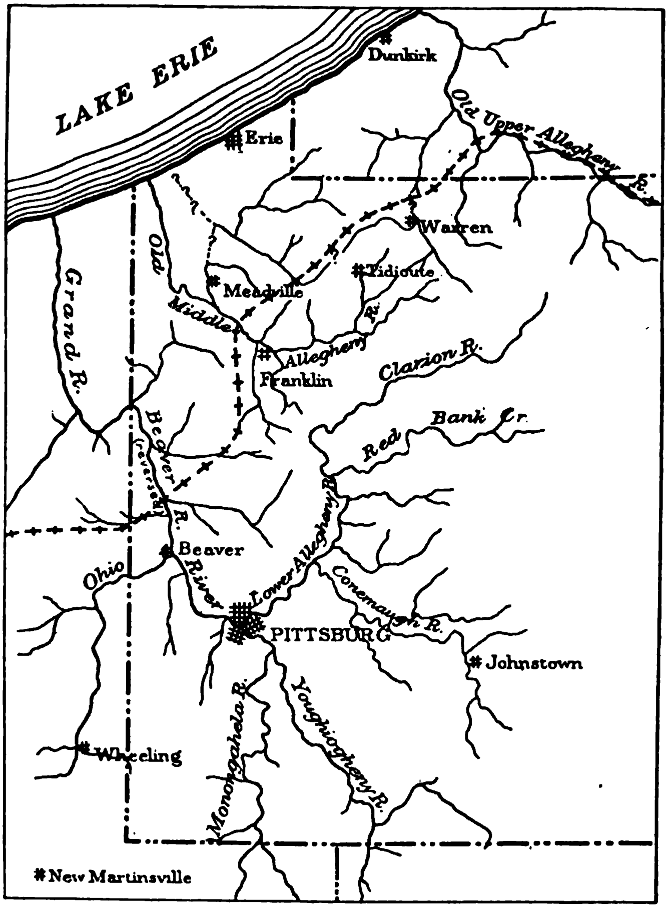

Fig. 4. Sketch map showing the probable pre-Glacial drainage of western Pennsylvania. The terminal moraine is shown by a broken crossed line. (After Frank Leverett; with addition of terminal moraine.)

Further investigation developed the fact that another stream nearly coincident with the present course of the Ohio between Wheeling and Beaver flowed northeasterly. The divide at the head of this stream was in the vicinity of New Martinsville.

The Allegheny river also is a striking example of drainage changes. Some of its affluents in Cattaraugus and Chautauqua counties, New York, and Erie county, Pennsylvania, have their sources on the southern slope of an elevated region which overlooks Lake Erie at points only 7 to 15 miles distant from the lake, yet they take a course directly away from the lake and join the drainage to the Gulf of Mexico. The apparently anomalous course of Allegheny river is due to the fact that it was formed by the union of a number of independent streams, parts of which originally flowed north into the basin of Lake Erie. As shown by the sketch map, the upper part found an outlet to the northwest by Salamanca to Gowanda, thence down Cattaraugus Valley. The middle portion from as far south as Emlenton flowed through Venango, Crawford and Erie counties, Pennsylvania, along a channel now utilized in part by French and Conneaut creeks and into the Erie basin just east of the Ohio-Pennsylvania State line. The waters of the Clarion and lower Allegheny, with its tributaries, followed the present course of Allegheny river, to the mouth of Beaver river, where they turned abruptly to the north and followed an old valley occupied in part by Beaver and Grand rivers to the Lake Erie basin.

Another interesting case of diversion is that of Raccoon creek in the Beaver quadrangle. This creek, which now empties into the Ohio three miles below Beaver, originally turned to the east at New Sheffield and emptied into the Ohio several miles above the big bend at Beaver.

This diversion of the streams which formerly flowed into Lake Erie was brought about by the continental ice sheet, which, in the Glacial epoch, extended down across the Great Lakes and into Pennsylvania as far as the broken crossed line on the sketch map (Fig. 4 above). The north-flowing streams were ponded against the ice front, overflowed their divides, and cut new channels, forming the present system draining into the Mississippi river.

Abandoned Channels. Among the most interesting features of the topography of western Pennsylvania which have been brought to light by the recent topographic and geologic mapping are the numerous abandoned channels along the larger north-flowing streams. Attention was first called to them by M. R. Campbell in the Masontown-Uniontown folio, and they have been discussed also in the Brownsville-Connellsville folio. The extent of these abandoned channels is shown in the accompanying figure, which is a map of the quadrangles along the Monongahela between Pittsburg and the State line.

This map shows the course the streams have occupied at different periods of their history. The present courses of both Monongahela and Youghiogheny rivers are seen by this map to differ considerably from their earlier courses.

These abandoned channels, which are broad, open valleys with nearly flat floors, are now occupied by very small streams, if they are drained at all. One of the largest is the great Carmichaels bend in the Masontown quadrangle. From the distant hills the observer would expect to find the Monongahela river flowing through the large, open valley in which Carmichaels is located, but the present stream is hidden in a deep gorge at some distance on the east. The abandoned channel is a rock-cut valley filled to a depth varying from a few feet up to 60 or 70 feet, with stratified clay and sand, which indicates plainly its river origin. Sub-angular blocks of sandstone measuring 4 or 5 feet in their largest diameter are present in the midst of fine material, especially in the little amphitheater opposite Bellevernon. These cannot be accounted for only on the supposition that they have been floated into their present position on blocks of ice. This abandoned valley at Bellevernon is one of the most interesting examples of its kind. It is not a simple channel, but there are two distinct valleys and a third of questionable character, besides the channel of the modern stream. From the great depth of filling it seems probable that the outermost channel is the one origi-

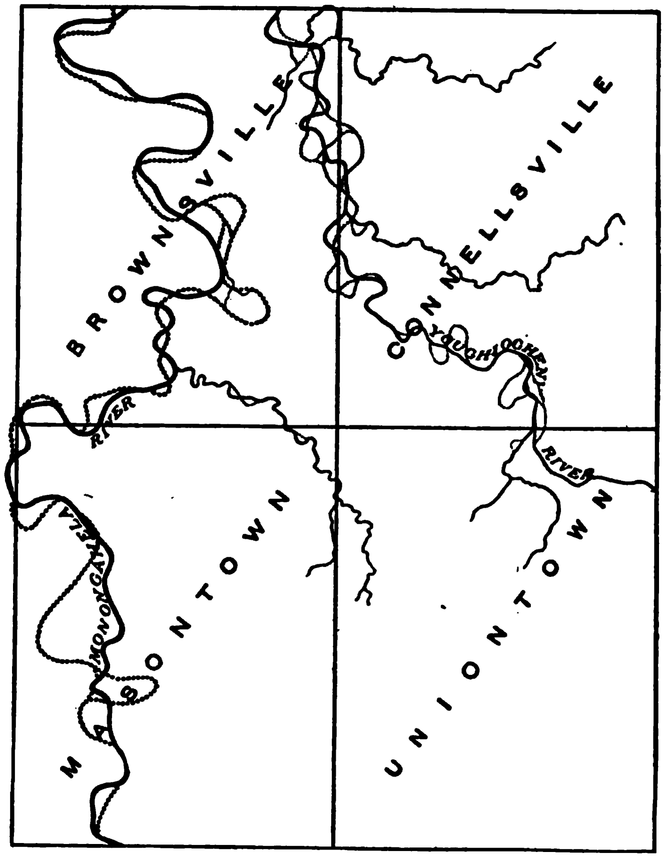

Fig. 5. Sketch map of quadrangles in western Pennsylvania showing pre-Pleistocene and recent courses of the Monongahela and Youghiogheny rivers and their larger tributaries. Present drainage indicated by solid lines, pre-Pleistocene by dotted lines.

nally occupied by the river and that this was abandoned in favor of the shorter course which was occupied for so long a time that it was cut as broad as the original channel. The original course of the stream was across the sites of Fayette City and Arnold City, and thence along the broad, open valley to Bellevernon. The second course separated from the first near Arnold City and united with it again just back of Bellevernon. The topography at Pittsburg indicates that originally the Monongahela flowed north from the present site of Homestead through Wilkinsburg and made two loops which impinged on the bluff now forming the north bank of Allegheny river near Sixmile Island and Millvale. East Liberty and Roup are at the points where the old river cut off these ox bows, and turning to the south through Oakland, reached its present course at Southside, and thence flowed on to Beaver and north into Lake Erie.

Youghiogheny river has suffered as severely as the Monongahela. Being a smaller stream, its bends are not so large and pronounced, but many of them are equally well developed and are well preserved.

These abandoned river channels constitute the most striking topographic feature of the region. They have long been recognized as such by geologists but no adequate explanation of their origin was offered until that advanced by M. R. Campbell in the Masontown-Uniontown folio. According to his observations, abandoned river channels of the character here described are limited to the following streams: Allegheny, Kiskiminitas, Youghiogheny, Monongahela, Kanawha, Guyandotte, Big Sandy, Kentucky and Ohio rivers. These streams are located a short distance south of the limit of glaciation, therefore, the abandonment of the channels seems to be due to some condition induced by the presence of the ice sheet. Still further, it is noted that abandoned channels are most abundant on streams that flowed to the north or northwest directly toward the ice front. In this connection, it may be noted that the drainage of the upper Ohio has suffered decided changes through the advance of the Glacial ice sheet. It is now fairly well established that the present Allegheny river system was formerly divided into three parts, all of which drained into the St. Lawrence basin, as previously described. The waters of the Monongahela river also found a northern outlet through Beaver river into the same system. Kanawha river, with its tributaries, Guyandotte and Big Sandy, flowed northward through the present Scioto Valley and probably constituted a branch of the river system which occupied the basin of Lake Erie. The advancing ice sheet is supposed to have dammed these northward-flowing streams and forced the water to seek another outlet along the present course of the Allegheny and Ohio rivers. In this pond which was

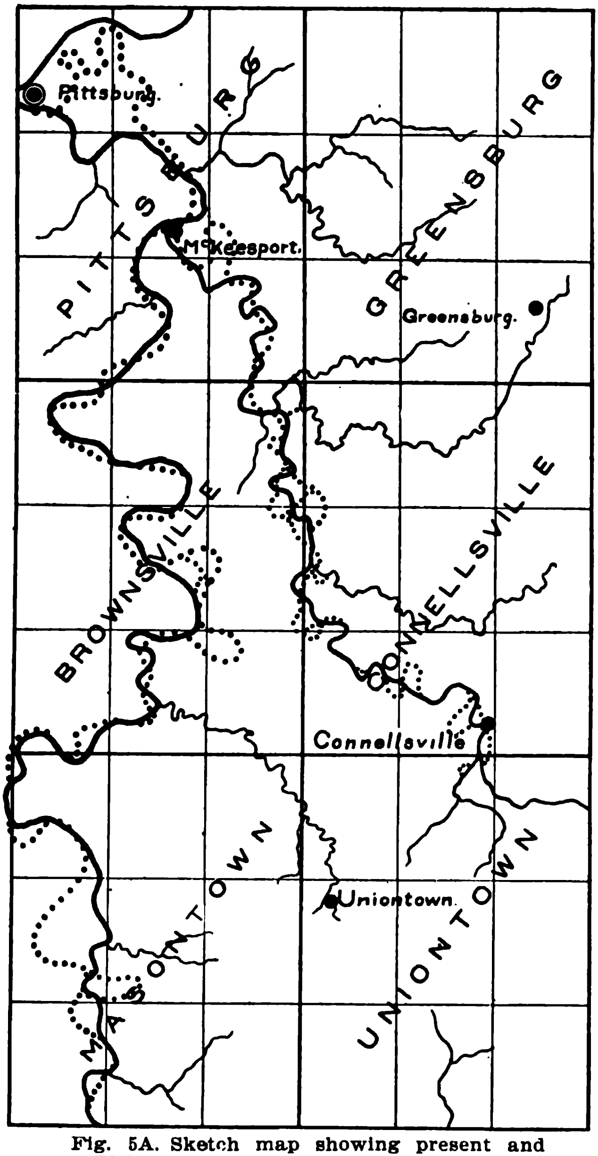

Fig. 5A. Sketch map showing present and pre-Pleistocene courses of Monongahela and Youghiogheny rivers.

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formed along the ice front, silts were deposited, but it is not possible to ascribe the abandoned valleys of the upper portions of the Monongahela and Youghiogheny to this ponding. The changes in the aligament of these streams must have been due to local conditions. The glacial ice sheet did not reach so far south, and hence, it could not have been directly instrumental in producing them. It seems probable that ice in the rivers which flowed north or toward the ice front, formed jams or gorges in the rivers during the summer break-ups. It is possible that immense dams built by floating ice during the summer were not melted away before an ensuing winter fixed them firmly in position. Increasing in size and strength season after season, the pond produced by such dams must have accumulated immense quantities of silt which eventually filled up the former river valley and diverted the stream to another course. The location of these dams can not be definitely determined in all cases at the present day, but some of them are distinctly shown by the deposits of sand and gravel now contained in the abandoned valleys. In the abandoned valley at Carmichaels, for instance, which has a length of 8 miles, the upper part for a distance of about 6 miles is filled from 10 to 80 feet deep with alternating beds of sand and clay. About 2½ miles northeast of Carmichaels these deposits end abruptly and the valley floor below this point shows a filling of only a few feet of sand and gravel. This lower portion is apparently left in the condition in which it was occupied by the Monongahela before the barrier was formed which permitted the silting up of this upper course, and the location of this barrier is definitely determined by the northern limit of the heavy silt deposits. Each of the abandoned valleys of the Monongahela may be explained by the existence of a local barrier of ice in some part of its course. In the case of multiple channels, as at Bellevernon, it is necessary to assume the existence of several dams.

Further description of these changes in the drainage of western Pennsylvania will be found in the folios descriptive of the areas through which the larger rivers flow.

STRATIGRAPHY.

GENERAL STATEMENT.

The rocks of southwestern Pennsylvania are in the main of sedimentary origin, i. e., they were originally deposited as sediments in the form of sand, clay, lime and mixtures of these, and afterward consolidated into rocks. In addition, there are coal beds of the same age as the consolidated rocks, some of which were probably deposited as sediments formed of vegetable matter, spores of plants, etc., though in the main the coal beds are the result of the accumulation of vegetable matter in swamps where it grew. Covering the surface are the soils resulting from the weathering of the underlying rocks, alluvial deposits along the river bottoms, sands, clays and gravels covering the elevated benches or upland flats, which represent river deposits when the rivers were flowing at higher levels than at present, the present valleys not having been cut down. In the region of New Castle in the northwest corner of the area treated occurs the edge of the great blanket of deposits laid down by the ice during the Ice age. Finally, in a mine near Masontown, in Fayette county, has been reported a dike of peridotite, an igneous rock that was forced into its present position when liquid or plastic.

The unconsolidated rocks on the surface all belong to the Pleistocene, or last geologic age. The consolidated rocks belong to the Carboniferous, or age of coal, or to earlier ages, except the dike mentioned, of which the exact age is not known. Nearly all of the consolidated rocks outcropping at the surface in this area belong to the Carboniferous age; the older, or underlying rocks, though exposed abundantly to the east of this area, are here seen only in some of the anticlines, especially where they are cut across by the larger streams. They are also found in wells which are drilled for oil and gas.

The principal divisions, subdivisions and formations into which the rocks of this area are divided according to age are shown in the following table:

SUBDIVISION OF ROCKS OF SOUTHWESTERN PENNSYLVANIA ACCORDING TO AGE.

- Pleistocene—
  - Surface soil.
  - Alluvium.
  - Wisconsin till.
  - Outwash, gravels, etc.
  - Kansan till.
  - Carmichael's clay.

Post-Carboniferous—
- Peridotite of Fayette county.

Carboniferous—
- Permian, or Dunkard, or "Upper Barren Measures."
  - Greene formation.
  - Washington formation.
- Pennsylvanian Series—"Coal Measures Groups."
  - Monongahela formation, or "Upper Productive Measures."
  - Conemaugh formation, or "Lower Barren Measures."
  - Allegheny formation, or "Lower Productive Measures."
  - Pottsville Group (or formation in Pennsylvania).
- Mississippian Series, or Lower Carboniferous.
  - Mauch Chunk formation.
  - Burgoon (Logan, "Big Injun") sandstone.
  - Cuyahoga (shale, limestone, and sandstone).
  - Berea (Corry) sandstone.
- Catskill-Erie.
  - Knapp formation.
  - Conewango formation.
- Devonian.
  - Chemung formation.
  - Portage formation.
  - Genessee shale.
  - Hamilton and Marcellus formations.
  - Oriskany sandstone.
  - Helderberg limestone.
- Silurian.
  - Waterlime group.
  - Salina group.
  - Niagara group.
  - Medina group.
- Ordovician (Lower Silurian).
  - Hudson River shales (Lorraine).
  - Utica shales.
  - Trenton limestone.

There is an inclination on the part of many to criticize the introduction of new names in the nomenclature of the geology of Pennsylvania, or a failure of the latter-day geologist to recognize the correlation of rocks or members whose absolute identity had formerly not been questioned. It should be remembered that the advance of science and civilization has been largely due to the substitution of the weighing balance for the "hefting" by hand, of the straight edge or transit for the squint of the eye, of the foot rule and tape for the estimate or pace. The advance has been from rules, theories and laws, based on partial data, vague surmises, estimated figures and dimensions, and pure guess work, to rules, theories and laws based on more complete data, on accurately measured dimensions, weights or distances; in general on more accurate and more complete information. In many cases this gain in the amount and accuracy of the information has only tended to strengthen and establish rules already laid down. In other cases, it has tended to give them more definite form, in still others the more complete and accurate data has tended to show that conclusions based on the information first obtained were entirely erroneous.

The data upon which the conclusions of geologists are based have always been and in a large measure must always continue to be obscure and partial. A large part of the data are hidden away underground; a large part of them have been matters of time and disappeared long ages ago. Nevertheless the operations of mining and prospecting, especially prospecting with the core drill, have substituted a great amount of accurate information in some regions where before all was guess work. When a mine driving through a hill connects absolutely a thick outcropping coal on one side of the hill with a thin outcropping coal on the other, their identity has been established regardless of all that may have previously been said against their identity. The Redstone coal was originally determined as 50 feet above the Pittsburg coal at its type locality. Mine shafts at the same points have demonstrated that the coal is over 80 feet above the base of the Pittsburg bed. In a region in which the space occupied by the Kittanning coal group is found to contain only three coals these may well be called the Upper, Middle and Lower Kittanning, even though there may be a suspicion, frankly stated, that they do not all correspond exactly to the beds similarly named in the type region on the Allegheny river, but when in an adjacent region five or even seven coals are found in that same space, then it is evident that if names are to be applied at all, the old names can be applied only on the assumption that the increase in the number of beds is due to the splitting of the three original beds. If, however, facts be obtained that either prove that the increase is not due to the splitting of the beds or render such an explanation highly improbable, then some of the beds must go unnamed or new names must be applied. A new difficulty arises in determining which of the two or three in the middle of the group should be called the Middle Kittanning, et cetera. Then having determined that, it may be found that this Middle Kittanning does not correspond with what we have called the Middle Kittanning in an adjacent region where there are only three coals. In other words, when an increasing number of facts make more and more doubtful the exact correlation or identity of any two sandstones, coals, or other members, it is not in accordance with scientific or practical progress to continue to assert their identity, no matter how fondly or how long such an idea has been held.

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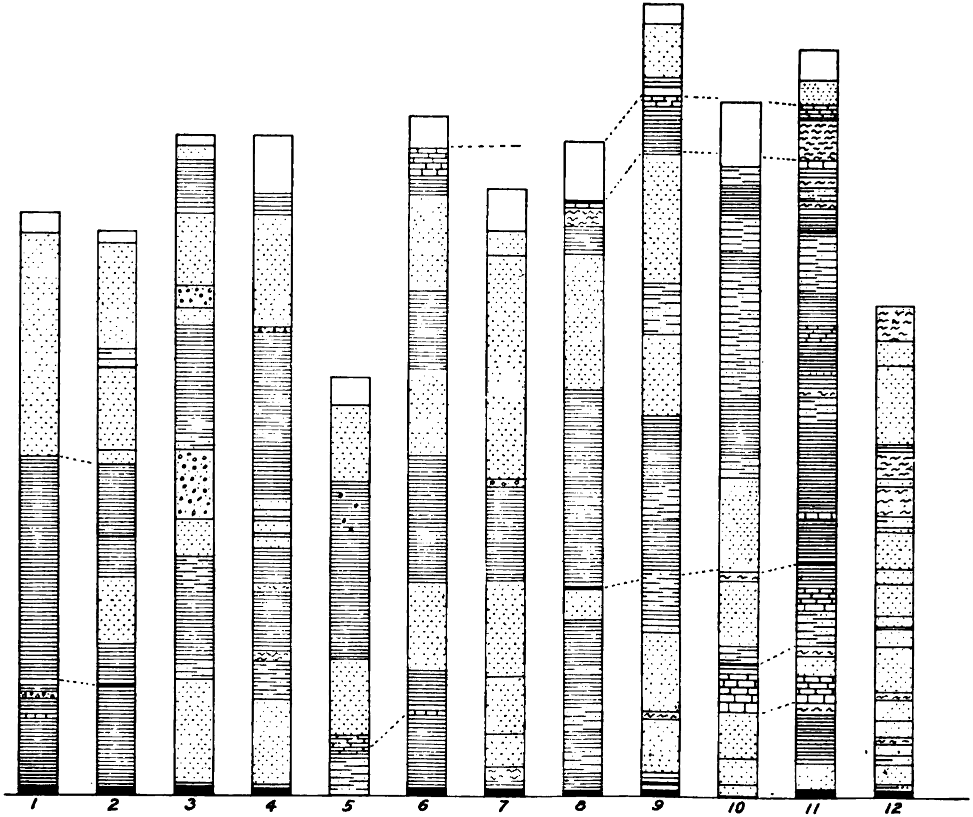

Fig. 6. Selected sections of the lower half of the Conemaugh formation from a small area in Jefferson County. To show the variability of the rocks in that part of the column. Scale 1 inch-100 feet.

It is often asserted that the old stratigraphic names, based as they were on the old stratigraphic column of New York, as worked out by the Hall Survey, are good enough. To such a one it is recommended that they read the reports of hte State Geologist of New York for the recent years. Thus it may be a matter of surprise to some to learn that the Niagara, Clinton, Medina and Oneida, of eastern New York, have been replaced by Cobleskill, Decker Ferry, Bossardville, Poxino Is., Binnewater sandstone, High Falls shale and Shawangunk.* Recent work seems to have demonstrated that while the first named rocks were being deposited in western New York a land period existed in eastern New York, so that no rocks were deposited there during those periods, and a perusal of recent geologic literature on New York State would reveal a host of strange names to one who knows the geology of that state only through the writings of Hall, Dana and the older workers.

Nevertheless, it is the policy of the members of the U. S. Geological Survey working in Pennsylvania to preserve the old nomenclature just as long as a reasonable doubt in favor of its correctness exists, even though the evidence in general may point strongly to its incorrectness. In other cases the old names have been used in a successional sense, though stated frankly that their use is not intended to imply exact correlation.† It is undoubtedly in a large measure the province of the geologist's work to determine and to declare the correlation of rocks or coal beds existing in different places, but it is exactly as much the province of his work, when and where necessary, to demonstrate lack of correlation where it may have been assumed, when the facts prove or render highly probable such lack of correlation.

In the description of the formations and members that follows, while the writer has tried to review all of the literature on the subject, he must express his especial obligation to I. C. White's U. S. Geological Survey Bulletin 65 on the Stratigraphy of the Northern Appalachian Coal Field. This has been especially true of the members above the middle of the Conemaugh, with which the writer's personal acquaintance is slight.

The detailed studies of the stratigraphy made in connection with the recent work has led to a better understanding of the relations and variability of the beds of rock in the Carboniferous or coal measures than has been possible before. This has mainly been due to two things; (1) the fact that the method used required the taking of continuous sections, so that the persistence or variation of each rock stratum was traced from hill to hill. Measurements and descriptions were made of its thickness and character on each hill

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*New York State Museum, Bull. 107, p. 51, 1907.
†As for example Folio No. 102, Indiana, p. 4, bot. col. 4.

upon which it is exposed; and (2) the members of the Survey have had access to the records of hundreds of diamond core drillings which are usually in great detail. Thus in many of the quadrangles several hundred vertical detailed sections have been obtained. As is often the case, this abundant data has frequently rendered difficult and obscure stratigraphic problems that with meagre data seemed simple and clear. This will be evident from a study of figures 6, 7 and 8, on which are given columnar sections selected within fairly narrow limits. Figure 6 gives a grouping of sections in the lower half of the Conemaugh, in which with one exception the distance from one of these sections to the next is less than two miles, and in five cases less than one mile. Between the first and second and the fourth and fifth there is a space of only one-fourth mile. Figure 7 is another series of sections of the lower part of the Conemaugh, selected from an area four miles long by two miles wide. In this figure the vertical scale is two times that of the preceding

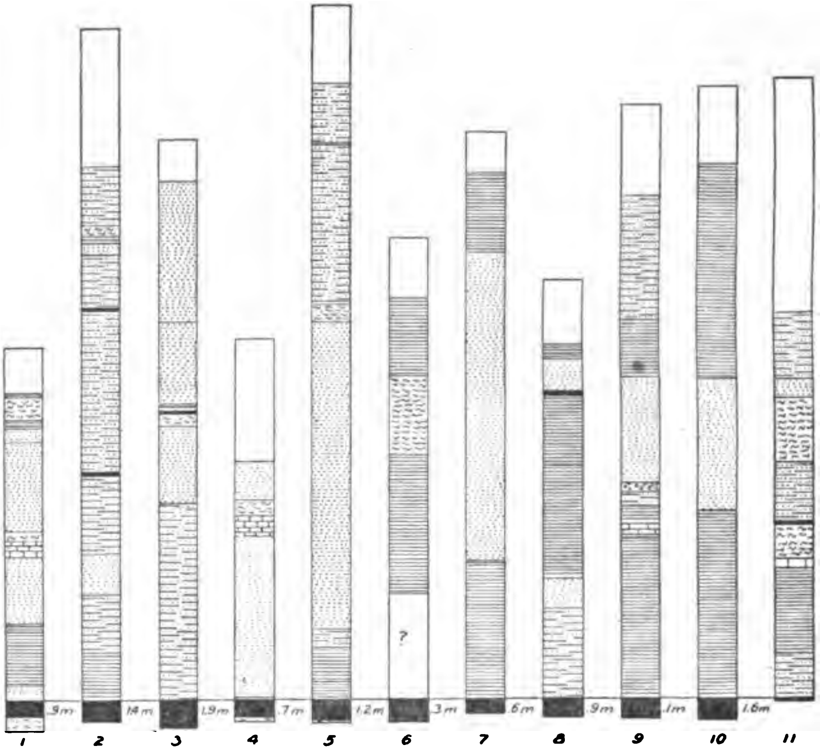

Fig. 7. Selected sections of the lower part of the Conemaugh formation from an area 4 miles long by 2 miles wide, in Indiana County. To show in even more detail the variation within narrow limits. Scale: 1-inch-50 feet. The figures between the sections give the distance of the sections apart in miles and tenths of a mile.

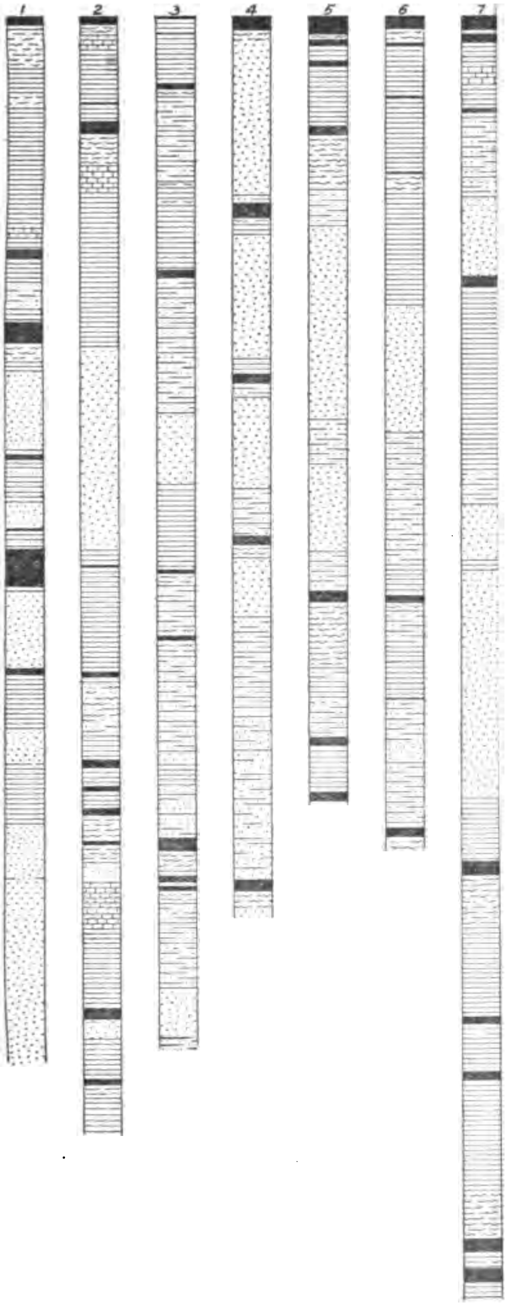

Fig. 8. A selected series of sectio
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Scale: 1 inch-50 feet.

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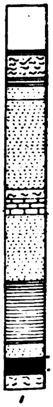

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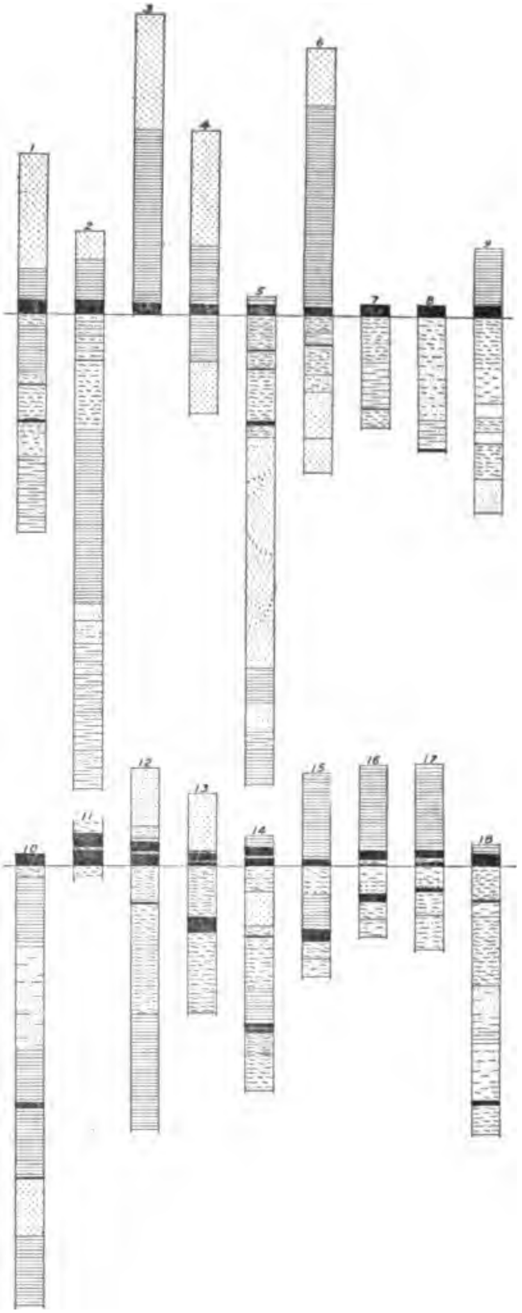
figure, in order to bring out more clearly the variations. Certain facts become immediately apparent on the study of these sections. The most prominent fact is the extreme irregularity of the sandstones and shales. A sandstone in one section has entirely thinned out before the next section is reached, one-fourth mile away. Sandstones which apparently are the same in two adjacent sections may differ by from 5 to 50 feet in the distances from their tops down to the key horizon (in this case the "E" coal). Unfortunately, in most of the coal measure areas the sandstones are almost the only outcropping rocks, though often their outcrops consist only of scattered sandstone fragments, and in many areas their outcrops are the sole key to the position of the hidden rocks. It is often stated by mining men or geologists that they have traced a certain sandstone from one district to another many miles away. As a better understanding of the stratigraphy of the coal measures is gained, such statements are received with more and more reserve.

Turning to the small coals of the sections the case seems but little less hopeless, though not quite so much so, and if the limestones be considered it would seem that while the coals and limestones of one section may not appear in the next section adjacent, there is a visible tendency for them to reappear at about the same position in some other section. This is especially true of the limestones. Thus note the recurrence of a limestone about 40 feet above the "E" coal at the base, and again near the top of several of the sections in figure 6. Lest it be thought that this irregularity is local in the part of the section selected for the figures 6 and 7, figure 8 gives a group of sections of the Allegheny formation, all within a space of a few miles in Clearfield county. The sections in figure 9 are given to illustrate still further and in greater detail this tendency to variation in the coal measure rocks. These sections were all personally measured by the writer in the railroad cuts along the west branch of the Susquehanna river between Curwensville and Clearfield. The railroad follows the strike of the rocks so closely that the main coal of the sections is exposed in nearly every cut between the two places. Often the exposures are several hundred yards in length, so that it is possible to trace clearly the pinching out of coal beds two feet or less in thickness, and the changes from sandstones to shales.

In the preceding paragraphs the emphasis both in the figures and in the text has been on the variability of the coal measure rocks, and too much emphasis can not be put on that side of the problem, for though every one who studies the coal measure rocks realizes somewhat that variability in theory, in actual practice he is very apt to neglect it and to assume regularity to within very narrow



1. Cut on New York Central Railroad halfway between two county bridges south of Curwensville.

2. Cliff near new county bridge 2 miles south of Curwensville.

3. One-quarter of a mile west of New York Central Railroad's temporary depot.

4. Cut under road just south of temporary depot of New York Central Railroad.

5. Cut just east of Buffalo, Rochester & Pittsburg depot at Curwensville.

6. Cuts, Pennsylvania and Buffalo, Rochester & Pittsburg Railroads just at east edge of quadrangle, near Susquehanna bridge.

7-8. Cuts, Pennsylvania Railroad, just east of Carbon mine.

9. Cut, Pennsylvania Railroad, a little east of Nos. 7-8.

10. Cut. Pennsylvania Railroad, west of River View Station.

11-13. Sections in stripping between River View and road south from West Clearfield.

14. Section of bank, Buffalo, Rochester, & Pittsburg Railroad, opposite River View.

15. Cut. Buffalo, Rochester & Pittsburg Railroad, opposite Clearfield.

16. Cut, Buffalo, Rochester & Pittsburg Railroad, 100 feet east of No. 15.

17. Cut, Buffalo, Rochester & Pittsburg Railroad, 120 feet east of No. 16.

18. Cut, Buffalo, Rochester & Pittsburg Railroad, just north of Pennsylvania depot, Clearfield.

Vertical scale: 3 inches-100 feet.

Fig. 9. Showing variable character of a part of the Allegheny adjacent to the Lower Kittanning or "B" coal as exposed in railroad cuts between Curwensville and Clearfield, Clearfield County, Pa.

limits. This has led to conceptions of stratigraphic simplicity in the past that not only have been very misleading and the cause of innumerable mistakes of correlation, but that must be replaced by a more correct conception before correct and reliable results can be obtained in the field.

After such a statement of the case, the reader may be inclined to ask what basis exists for the accurate determination of the stratigraphy and structure of the coal measure rocks. It has been shown that the sandstones are especially irregular and unreliable for tracing the stratigraphy from place to place. In fact, the recent work has shown that in many cases the sandstones that have always been assumed as very persistent and horizon markers of great values, are actually at quite distinct horizons; that they never connected horizontally; that they were often deposited at distinctly successive periods, and that any conclusion based on the assumption that they are the same is necessarily erroneous. Thus, when it is found that one of two sandstones supposed to be the same was deposited under or before a certain coal bed or limestone bed, and the other above or after it, it is evident they can not be the same. In the second place it has been shown that too much reliance can not be placed in the persistence of the smaller or minor beds of coal, and the same is true to some extent of the limestones. It may be further shown that the coal beds of seeming importance

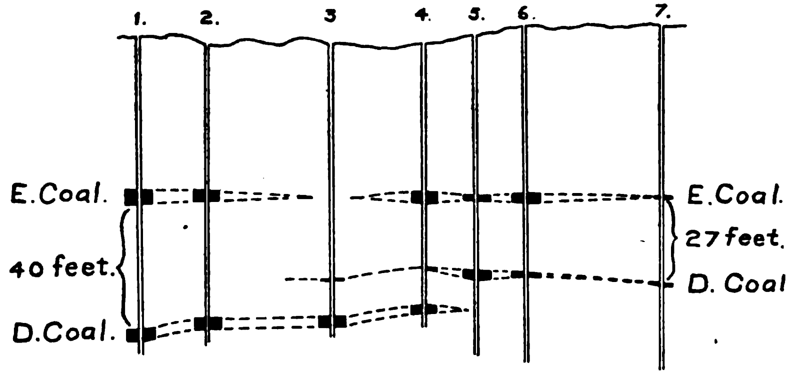


Fig. 10. Sketch showing relation of coals at horizon of "D" or Lower Freeport coal in Northern Cambria County. (After Campbell.)

may be non-persistent. Thus figure 10 shows a case from Cambria county where what has always been assumed beyond doubt was the Lower Freeport coal at two points not far distant has been shown by detailed drillings to be two thick coal beds lying at slightly overlapping horizons, each of which thins out in the region of the strong development of the other. Or again, in Clearfield county what has been considered the Lower Freeport coal splits in going westward from the region of its magnificent development from Houtzdale to Philipsburg and beyond (see figure 11). After tracing the split several miles, or until the benches are 40 to 50 feet apart, data become meager for several miles. Do the two benches come together again farther west, does one bench feather out, or do they both continue and pass under different names? Similar cases could be cited of the "B" coal in Clearfield and again in Clarion county, and so of other coals.

But on the other hand there are several elements in the coal measures of Pennsylvania that appear to have been laid down over large areas. Thus the Pittsburg coal has been stated to underlie an area in Pennsylvania alone of 2,126 square miles, and evidently originally underlay a much larger area, and in this case leaving out of account minute remnants of thin coal in Cambria county that may be Pittsburg, there is practically no shadow of doubt of the original continuity of this bed wherever found in Pennsylvania. Over large areas there is little less doubt of the original continuity of the Ames or crinoidal limestone in the middle of the Conemaugh formation, and the same is true of the Vanport or old "ferriferous" limestone occurring near the bottom of the Allegheny formation. These three elements of the section may be considered as the great key horizons; then come a large series of elements that seem to have a fair degree of persistency. Thus usually from 15 to 85 feet above the Vanport limestone occurs a coal bed which is so regularly underlain by a thick clay that the three elements taken together are thought to establish a widespread correlation of that coal which has been called the Lower Kittanning. But where the interval from the coal to the limestone changes from 84 feet, as it is opposite Beaver Falls, to 25 feet at less than 10 miles to the north, it leads to the question whether the coals are the same. The splitting of this bed in Clearfield county, the appearance of a new bed between it and the limestone in Clarion county, the stratigraphic irregularities such as those illustrated from the west branch of the Susquehanna, indicate that the Lower Kittanning coal is not an ideally persistent stratum, and yet there are large areas in which it remains so constant as to serve admirably within those areas as a key rock.

On the whole, because of the check on the Vanport limestone, the position of this coal is better determined than that of any other of the lower coals. Above this coal for 200 feet are usually found a number of coals, some of which are usually important, and at the top of this series is quite widely found a coal of some importance that has been called the Upper Freeport. In some limited areas this coal is quite persistent, and it frequently happens that where it is not persistent there occurs a short distance below

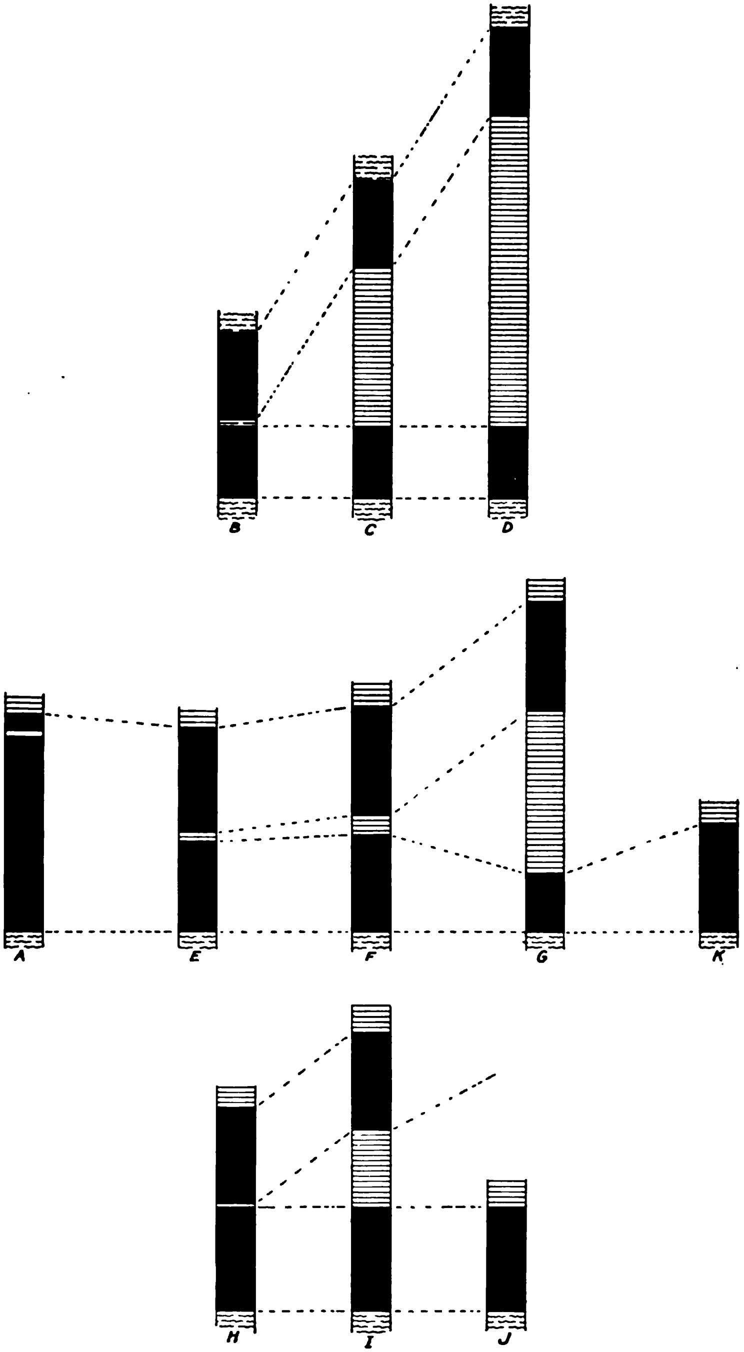


Fig. 11. Sketch illustrating splitting of "D" or Moshannon coal west of Houtzdale, Pa.

A, section in the Cross Keys mine, typical of "D" coal around Houtzdale and to the eastward.

B, C, D, three sections in the Yorkshire mine; from B to C 30 feet; from C to D 100 feet, (showing splitting).

E, F, G, three sections in the Webster No. 4 mine.

H, I, J, three sections in the Falcon No. 2 mine; H and I at back of mine (at east); J from west end of mine.

K, section (lower bench) from Eureka No. 22 mine, typical of mines at Muddy Run. Upper bench 12-55 feet above and not mined.

Vertical scale of coal sections: 1 inch=5 feet.

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the Lower Freeport coal that locally is thick and persistent. Furthermore, other features near this coal bed help in its identification. There is frequently below it a bed of limestone. As the first coal above it and the first two coals below are also frequently underlain by limestone, this in itself has but little value, but the limestone above is usually quite ferriferous, frequently verging over toward an iron ore, and the coal associated with this ferruginous limestone is usually very small, generally only a few inches, though locally it becomes workable. But further there is frequently associated with this Upper Freeport coal some drab flint clay (Bolivar clay). This has been quite widely noted in Clearfield, Indiana, Jefferson, Clarion, Armstrong, Fayette, Westmoreland and other counties. There is also a flinty shale to a flint clay below the coal next above; but this clay is very impure, usually olive in color, quite noticeably ferruginous, and comes some little distance below the coal. The coal below the Upper Freeport has not yet been found to be associated with flint clay, though the evidence is negative. Furthermore, there is frequently a small amount of red shale associated with the Mahoning coal, the first coal above the Upper Freeport, that is noted with the Upper Freeport in Pennsylvania. In the earlier work the Upper Freeport was frequently recognized by its presence under a massive sandstone, supposed to be the Mahoning. It is true that in the bluffs opposite the town of Freeport the Mahoning sandstone overlying the Upper Freeport coal is magnificently developed, but the recent work seems to show that the Upper Freeport coal is more frequently overlain by shale than sandstone, and that often the so-called Mahoning sandstone has red shale below it and turns out not to be just where it had been thought. These are a few of the minute distinguishing features that have been used to identify the Upper Freeport coal. In the same way other distinguishing features have been used in identifying some of the other beds. Thus flint clays, in addition to their occurrence below the Mahoning and the Upper Freeport coal, are commonly found below the Upper Kittanning, and very commonly below the Lower Kittanning coal. The Upper Kittanning is the cannel coal bed of Pennsylvania. Probably every deposit of cannel coal of workable dimensions comes in the position of the Upper Kittanning coal. This is true in Centre, Clearfield, Indiana, Armstrong and Beaver counties, as far as recent studies go. Were it possible to get enough data, it would be possible to show just the extent of each of these sandstone lenses, the correlation of each of the smallest coals, et cetera. In some cases much can be done where at first sight all is irregular and confused. Thus in beginning the study of the Clarion quadrangle it appeared that the "B" or Lower Kittanning coal was overlain indifferently by shale or sandstone; that the first coal above came anywhere from 18 to 80 feet above, et cetera. Later work showed that the "B" coal had originally been covered by a characteristic dark or black shale, that after the laying down of the dark shale coal-forming conditions had existed, resulting in a small coal and some black shale; this was followed by irregular uplift instead of subsidence; that erosion often cut down through the shales, frequently as sharp-banked channels, down to or into the "B" coal below; that subsidence with an incursion of sand followed, but the sand filling up the old irregularities tended to make a layer over the higher parts of the old surface 10 to 20 feet thick, et cetera. It was then easy to understand the variableness in the roof of the "B" coal, the occasional appearance of a coal only 20 to 30 feet above the "B" coal and its usual absence, et cetera.

The subject of stratigraphy has been here gone into at some length, in order to impress certain facts; first, that correlations based on offhand determinations due to supposed resemblances, are in most cases entirely worthless; second, that, as a rule, the sandstones are so variable, that their supposed tracing for long distances must always be open to question, and that correlations based solely upon the sandstones must be of very doubtful value; third, that, in many areas where the obtainable data are meager, it may be entirely impossible to reach positive conclusions as to the correlation of the coals and rocks of that area, but that, fourth, it is often possible to determine the stratigraphic relations of the beds over large regions where the data are very meager by a careful study of all of the minutia surrounding the beds of the section, and the careful tracing of those beds from place to place, in doing which these minutia may be brought to light, as well as from a knowledge of the original physiographic relations of the beds to each other, their distances apart, et cetera.

In a general way it may be stated that the beds above the Pittsburg bed appear to be more regular in their appearance and more constant in their distance from one to another than the beds in the lower part of the section, though recent accurate data, obtained from mine shafts and drillings, tend somewhat to shake that supposition. Further, along the eastern part of the area here studied, all of the three great key horizons fail, so that there is a somewhat greater element of uncertainty in the correlations there.

Mention must be made of the value from a stratigraphic standpoint of a study of the fossil plants associated with the coal beds in the hands of David White, of the U. S. Geological Survey. In general, the fossil plants vary but little in passing upward from bed to bed. The same species seem to recur from time to time, so that in the past they have been found to have little value. By a study of the minute variations of the different species, Mr. White has been able to detect as it were the changing fashions in the same species, and through these changing fashions, recorded by slight but distinct changes in the forms of the plants, he has been able to add a large amount to confirmatory evidence, and often to correct the correlations made purely on stratigraphic grounds.

Finally only the briefest mention must be made of the fact that probably during none of the great geologic periods were the physiographic conditions so unstable as in the Carboniferous, and every variation in every rock stratum, every lensing out of a sandstone, was the result of the changes in these physiographic conditions. Thus it is not far from true that every sandstone in the coal measures followed immediately a subsidence that had been preceded by uplift and erosion. In many cases the sandstone occupied only these eroded hollows. In other cases it was laid down on the irregular eroded surface, but to a great enough depth to cover that surface over large areas. So, too, the regularity or irregularity of each coal bed is largely an expression of the physiographic conditions existing at, before, or after its laying down. If laid down just after a period of uplift and erosion, it is apt to be irregular in thickness, pockety, et cetera. If its laying down was followed by uplift and erosion, it may again be irregular, but from a very different cause, and so on indefinitely.

The frequent occurrence of sandstones filling erosion depressions which have cut out the top of the coal is illustrated in plate XI, B.

CARBONIFEROUS.

DUNKARD SERIES.

Thickness, Character and Extent. The name "Dunkard," or "Dunkard Creek Series," was applied by I. C. White in 1891 to the deposits of this age from their fine exposures along Dunkard creek in Greene county. There remains a thickness of between 1,100 and 1,200 feet of these rocks, and an unknown thickness has been removed by erosion. In general, the rocks of this series consist of shales, shaly sandstones, limestones and coals. The limestones and coals are more important in the lower part of the series and to the northeastward in Washington county, though the coals are rarely workable. Going southward, all of the limestones but one, the Nineveh, disappear before reaching Jackson county, West Virginia. Red shales are abundant in the upper part of the section in West Virginia and in Greene county, but disappear toward Washington county. Some of the sandstones associated with red shales in the upper part of the section are very massive, though fine-grained.

The Dunkard rocks are confined to Greene and Washington counties, Pennsylvania, except small patches in Fayette, Westmoreland and Allegheny counties. They dip to the southwest so that their greatest thickness in the State is in the southwest corner, near the headwaters of Dunkard creek. The series is divided into two formations, the Greene above, and extending down to the top of the Upper Washington limestone, and below it to the top of the Waynesburg coal is the Washington formation. The composition of this series is shown in accompanying sections (fig. 12).

GREENE FORMATION.

J. J. Stevenson in his report on Washington and Greene counties* gives the following section from Centre township, which may be taken as a generalized section for Greene county.

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*Second Geological Survey of Pennsylvania, Rept. K, 1876, p. 35.

1. Section from Dunkard Creek, Greene county, Pa. (I. C. W., U. S. G. S. Bull. 65, p. 22.)

2. Section from Colvins Run, Greene county, Pa (I. C. W., U. S. G. S. Bull. 65, p. 23.)

3. Section from Aleppo township, Greene county, Pa. (I. C. W., U. S. G. S. Bull. 65, p. 24.)

G, Gilmore sandstone; N, Ninevah coal; N. 1, Ninevah limestone; F. C., Fishcreek sandstone; D, Dunkard coal; U. Wh., Upper Washington limestone; M. Wh., Middle Washington limestone; Wh. A., Washington "A" coal; L. Wh., Lower Washington limestone; Wh. Washington limestone; Wb. B., Waynesburg "B" coal; Wb. A., Waynesburg "A" coal; Wb., Waynesburg sandstone.

Vertical scale: 1 inch=200 feet.

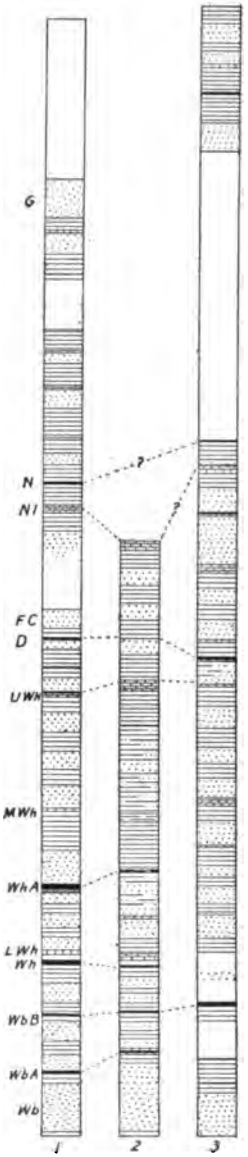

Fig. 12. Selected sections to illustrate the stratigraphy of the Dunkard rocks.

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GENERALIZED SECTION OF THE GREENE FORMATION IN GREENE COUNTY.

	Feet.	Inches.
Concealed,	80	
Limestone (XIV).	*	
Shale, reddish,	80	
Limestone (XIII),	4	
Sandstone,	50	
Limestone (XII),	10	
Sandstone and shale,	80	
Limestone (XI),	2	6
Shale, argillaceous,	12	
Sandstone,	30	
Coal. Nineveh,	1	8
Sandstone,	36	
Shale, bituminous,	1	
Limestone (X),	2	6
Sandstone, shaly, massive (Fish Creek),	100	
Coal, Dunkard,	1	6
Limestone (IXb),	3	
Sandstone and shale,	30	
Limestone (IXa),	6-15	
Shale, sandy,	70	
Limestone (VIII),	2-5	
Coal,	1	8
Sandstone,	19-30	
Limestone (VII),	2	6
Sandstone,	31	
Shale and iron ore,	10	
Limestone, Upper Washington (VI),		

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*Fragments.

I. C. White gives the following section of the Greene formation along Dunkard creek, the type locality:

DUNKARD CREEK, GREENE COUNTY, PENNSYLVANIA.

	Feet.	Inches.
1. Concealed from top of Shough's knob,	165	
2. Sandstone, massive, Gilmore,	40	
3. Shales, with limestone at base,	15	
4. Sandstone and shales and concealed,	100	
5. Shale, red,	2	
6. Shales, gray,	20	
7. Shale, marly,	2	
8. Sandstone and shale,	35	
9. Shale, red,	3	
10. Sandstone and shale,	50	
11. Red shale,	3	
12. Shales and sandstone, Nineveh,	25	
13. Shales,	20	
14. Coal, Nineveh,	1	6

DUNKARD CREEK, GREENE COUNTY—Continued.

15. Shales,	28	
16. Limestone (No.X), Nineveh,	7	
17. Shales, sandstone and concealed,	100	
18. Sandstone, massive, Fish Creek,	20	
19. Shales with fossil plants,	10	
20. Coal, Dunkard: Coal 5", Slate 1", Coal 6",	1	
21. Limestone,	1	
22. Sandstone,	10	
23. Shales,	17	
24. Limestone,	1	6
25. Shales and sandstone,	25	
26. Coal, Upper Washington,	1	1
27. Calcereous shale, fossilliferous, fish teeth,	0	6
28. Limestone, Upper Washington,	4	

CHARACTERISTIC MEMBERS.

Windy Gap Limestone. Windy Gap limestone has been named from its occurrence near Windy Gap, a "divide" in Spring Hill township, Greene county. It is a bluish gray limestone, quite pure and about five feet thick, containing minute fresh-water fossils. It is limestone No. XIV of Stevenson in Report K. It is found in Pennsylvania only in the highest points in southwestern Greene county.

Windy Gap Coal. Twenty-five to thirty feet above the last described member and about 1,050 feet above the Waynesburg coal is the Windy Gap coal, the highest coal, stratigraphically, in the Appalachian region. It is known only from blossoms. It is associated with black shale containing cypris.

Gilmore Sandstone. A massive, coarse-grained sandstone 25 to 40 feet thick, covers a considerable area around the heads of Dunkard, Wheeling and Fish creeks. It forms long lines of cliffs on the summits of the ridges and is good building stone. For 200 to 250 feet below the Gilmore sandstone the rocks consist mainly of red shale, an occasional thin limestone, and gray sandstone down to the sandstone next described.

Nineveh Sandstone. This sandstone, named from its occurrence near Nineveh, in Greene county, is a massive yellowish, gray, coarse-grained, rather soft, sandstone, splitting readily into rectangular blocks. It outcrops in great cliffs, and has been quarried extensively at Littleton and Jollytown.

Nineveh Coal. This is the uppermost of a series of five thin coals, sometimes known as the Bellton coal group, from their fine exposure at Bellton. It is seldom over a foot thick, but is highly prized locally for smithing.

Nineveh Limestone. This limestone has a thickness of about 10 feet, though often split up by shale partings until 20 feet thick. It is extensively distributed, being traceable near to the Kanawha river in West Virginia. It contain minute fresh-water fossils. It is limestone X of Stevenson in Report K.

Hostetter Coal. This coal occurs 75 to 100 feet below the Nineveh limestone. It is from 1 to 15 inches thick and rather pure. At Bellton it is 130 feet below the Nineveh coal.

Fish Creek Sandstone. One hundred and thirty-five to one hundred and fifty feet below the Nineveh coal is a massive cliff-making sandstone. It is very conspicuous along Fish creek, around Deep Valley, and above Littleton, West Virginia.

Dunkard Coal. Within 20 feet of the Fish creek sandstone occurs a thin, double coal, usually not more than 12 to 15 inches thick, but almost invariably double. At Deep Valley the parting thickens up to 5 feet. The-roof shales contain well-preserved fossil plants.

Prosperity Limestone.[*] This occurs 100 to 180 feet above the Upper Washington limestone. It is a hard, dark blue gray to nearly black, limestone with a thickness up to nearly 20 feet.

Tenmile Coal[†] *(Sparta Coal).*[‡] This coal has a thickness of from 1 to 3 feet or over. It contains thin partings, and occurs between a black shale and a shaly sandstone. It was erroneously called the Jollytown by I. C. White.

Donley Limestone.[‡] The Donley limestone occurs from 18 to 45 feet above the bottom of the formation, and in southwestern Washington county is invariably present where the horizon comes to the surface. It shows typically at Donley and Donegal township a thickness of 5 to 6 feet. It is hard and tough, dark steel-gray to almost black-colored, coarse-grained, and showing numerous calcite crystals, distinguished by its peculiar joining, which is in irregular blocks only 3 feet in diameter and in striking resemblance to that of dry mud.

Upper Washington Coal.[‖] This coal comes immediately on top of the Upper Washington limestone, imbedded in the black bituminous shale which generally overlies that limestone. The shale is uniformly present, but the coal is variable, its maximum thickness being not more than 14 inches, including shale and clay partings.

Other shales, sandstones and limestones occur throughout the formation, as shown by the sections.

WASHINGTON FORMATION.

General Sections.[§] The following section is a fair average of the extreme development of the Washington formation, in Washington county:

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[*] Economic geology of the Amity quadrangle. Bull. 300, U. S. Geological Survey, p. 28.

[†] Economic geology of the Amity quadrangle. Bull. 300, U. S. Geological Survey, p. 115.

[‡] Geology of oil and gas fields in Steubenville, Burgettstown and Claysville quadrangles. Bull. 318, 1907, p. 77.

[‖] Geology of oil and gas fields in Steubenville, Burgettstown and Claysville quadrangles. Bull. 318, 1907, p. 76.

[§] Geological Survey of Pennsylvania. Report K, 1876, p. 44.

GENERALIZED SECTION OF THE WASHINGTON FORMATION IN WASHINGTON COUNTY.

	Feet.
Limestone, Upper Washington,	30
Sandstone,	40
Coal (Jollytown),	1
Sandstone,	40
Limestone, Middle Washington,	15
Sandstones and shales,	60
Limestone,	8
Sandstone and shale,	20
Shale, bituminous or coal,	1
Limestone, Lower Washington,	20
Coal, Washington,	10
Sandstone, laminated,	12
Coal, little Washington,	1
Shale,	6
Limestone,	20
Coal, Waynesburg "B,"	1
Sandstone,	30
Limestone,	8
Coal, Waynesburg "A,"	2
Sandstone, Waynesburg,	60

The Dunkard creek section, by I C. White, in the type locality, is as follows:

DUNKARD CREEK, GREENE COUNTY, PENNSYLVANIA.

	Feet.	Inches.
Calcareous shale, fossiliferous, fish teeth,		6
Limestone, Upper Washington,	4	
Shales and sandstone,	115	
Limestone, Middle Washington,	3	
Shales,	40	
Sandstone,	35	
Shale,	5	
Coal, Washington "A;" Coal, impure, 1′ 2″; Fire clay, 2′ 6″; Coal, 6″,	4	2
Shales and sandstones,	60	
Limestone, Lower Washington,	5	
Shales,	5	
Coal, Washington, slaty,	5	
Shales and sandstones, including a coal bed near center,	110	
Coal, Waynesburg "A,"	2	6
Shales,	10	
Sandstone, Waynesburg,	50	
Shales, with fossil plants (Cassville),	5	
Waynesburg coal,		

Other sections are shown graphically in fig. 12.

CHARACTERISTIC MEMBERS.

Upper Washington Limestone. This is an important limestone in Washington county, where it is from 4 to 30 feet thick, and very pure. It is the topmost bed of the Washington formation, and, with the exception of the Waynesburg sandstone, the most conspicuous and persistent member of the Dunkard series. It occurs 670 to 710 feet above the Pittsburg coal, and 280 to 400 feet above the Waynesburg coal. It is a dark blue gray to blue black, or nearly black, limestone, weathering snowy white with a tinge of blue. It is hard, compact and brittle, usually separated into layers by thin beds of shale.

Jollytown Limestone. This is a hard, grayish, locally brecciated limestone, weathering light gray to dirty yellow. It occurs 30 to 40 feet below the Upper Washington limestone.

Jollytown Coal. A small coal coming a short distance below the Jollytown limestone.

Middle Washington Limestone. About midway between the Upper and Lower Washington limestones is the Middle Washington limestone, a very persistent stratum of Washington county. It is of a buffish color, and 10 to 20 feet thick. It is usually coarsely brecciated and contains numerous spots of crystal calcite. It is highly ferruginous and weathers to bright yellow.

Washington "A" Coal. An impure coal sometimes 4 to 5 feet thick, occurring 70 to 80 feet above the Washington coal, usually shaly, and often represented only by its bituminous shale.

Marietta Sandstone. The last-named coal is often absent and the rocks, for 100 to 125 feet above the Washington coal, are frequently sandstones in from 1 to 3 massive benches. This is less true in Pennsylvania than to the south and southwest, though locally this portion of the column contains massive sandstones in Pennsylvania. These sandstones are very prominent, and have been extensively quarried below Marietta, Ohio, Parkersburg and Elizabeth, West Virginia, and elsewhere. One of the beds makes the big cliffs on the hill above the famous McGugan gas well in Washington county.

Blacksville Limestone. A gray, pure limestone 3 to 5 feet thick occurs persistently 30 to 50 feet above the Washington coal in Washington and Greene counties. It is called Coal III by Stevenson in Report K.

Lower Washington Limestone. This limestone reaches its greatest thickness where it is 20 to 30 feet thick. It is usually interstratified with shale. Some of the layers are frequently ferruginous often to the point of being fair iron ore. It is usually hard and compact, light bluish gray, flesh-colored, weathering bluish white.

Washington Coal. This is the only widely workable coal in the Dunkard series. It occurs immediately below the Lower Washington limestone. It is always separated into two or three benches by shale partings, which greatly reduce its workability. It sometimes reaches a thickness of 8 or 10 feet, of which only the bottom (2 or 3 feet) are pure or merchantable. The upper part is usually shaly and high in ash.

Washington Sandstone. A flaggy, often finely laminated, brown, micaceous sandstone often underlies the Washington coal, being quite persistent in Washington and Greene counties of Pennsylvania.

Little Washington Coal. A thin, unimportant coal comes just under the Washington sandstone. It is most persistent in Washington county, and is seldom seen elsewhere.

Waynesburg "B" Coal. A somewhat more persistent bed of coal occurs about 45 feet below the Washington coal, having a thickness of 1 to 2 feet, though usually less.

Colvin Run limestone. A buffish, ferruginous limestone from 3 to 10 feet thick in Pennsylvania occurs 30 to 35 feet below the Waynesburg "B" coal. It is limestone I (a) of Stevenson in Report K.

Waynesburg "A" Coal. This coal occurs just under the limestone last mentioned. It is 60 to 80 feet above the Waynesburg coal. It reaches a thickness of 3 to 4 feet, but is usually shaly and worthless.

Mt. Morris Limestone. Two to five feet below the Washington "A" coal is a thin limestone, not always persistent. It is from 1 to 2 feet thick, except in Washington county, where it attains over 5 feet.

Waynesburg Sandstone. Two to five feet under the Mt. Morris limestone is the top of the Waynesburg sandstone, probably the most persistent member of the Dunkard series. Its eastern outcrop makes an almost constant line of cliffs from Greene county, Pennsylvania, to the Kanawha river in West Virginia. It reaches a thickness of 75 to 100 feet, and over wide areas is gritty or conglomeritic. This feature makes it an important key rock. It is usually of a grayish white to yellowish color.

Cassville Plant Shale. These shales are highly fossiliferous, dark gray shales, that sometimes intervene between the Waynesburg coal and the Waynesburg sandstone.

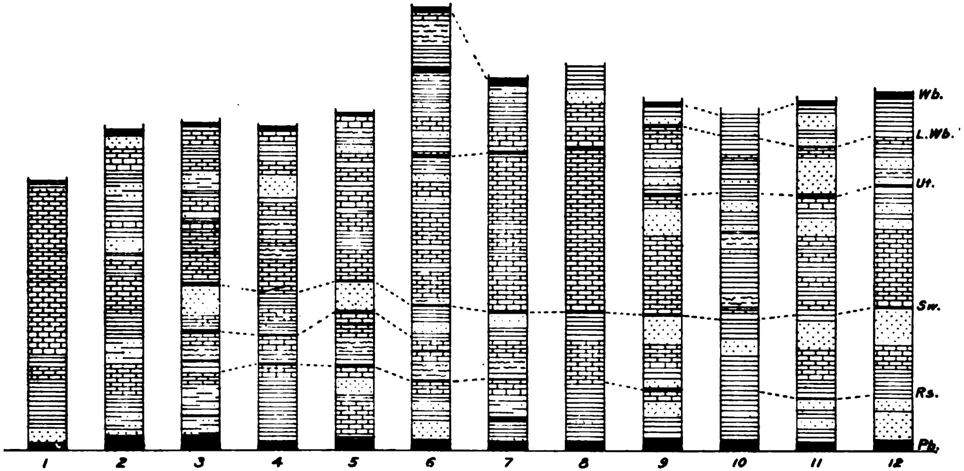

Fig. 13. Selected sections to illustrate the stratigraphy of the Monongahela rocks.

1. Section in an old shaft, Washington, (U. S. G. S. Bull. 300, p. 17).
2. Diamond drilling near Bissell (U. S. G. S., Bull. 300, p. 16).
3. Leisenring shaft No. 1, (U. S. G. S. Folio 82).
4. Leisenring shaft No. 2, (U. S. G. S. Folio 82).
5. Oliver shaft No. 1 (U. S. G. S. Folio 82).
6. Edenborn shaft (U. S. G. S. Folio 82).
7. Lambert shaft (U. S. G. S. Folio 82).
8. Buffington shaft (U. S. G. S. Folio 82).
9. General section, Fayette and Westmoreland counties (J. J. Stevenson, Second Geol. Survey of Pa. KK, p. 31).
10. Brownsville, Pa. (J. J. Stevenson, Second Geol. Survey of Pa., p. 233).
11. West Brownsville, Pa. (I. C. White, U. S. G. S. Bull. 65, p. 45).
12. Rices Landing, Pa. (I. C. W., U. S. G. S. Bull. 65, p. 45).

Wb, Waynesburg coal; L Wb, Little Waynesburg coal; Ut, Uniontown coal; Sw, Sewickley coal; Rs, Redstone coal; Pb, Pittsburg coal.

Vertical scale, 1 inch=200 feet.

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THE MONONGAHELA FORMATION, OR UPPER PRODUCTIVE MEASURES.

Rocks between the top of the Waynesburg coal and the bottom of the Pittsburg coal.

Thickness, Character and Extent. This formation extends from the top of the Waynesburg coal down to the bottom of the Pittsburg coal. Its thickness varies from 200 feet along the western outcrop in Ohio to 380 feet on the Monongahela river. It is said to reach over 400 feet in borings in West Virginia. In Pennsylvania it varies within somewhat narrower limits. The series is confined to the southwestern part of the State, occupying the whole of Washington and Greene counties, a considerable portion of Allegheny, Fayette and Westmoreland counties and small isolated areas in Somerset and Indiana counties.

At the northeast in Greene, Washington, Fayette and Westmoreland counties, limestones make up fully one-half of the rocks of the formation, and in this region the formation contains at least six distinct coal beds, three of which are valuable. There are also shales and sandstones. Going southward or southwestward, the limestones disappear, and all of the coals, except the Pittsburg bed. In place of the limestones appear red shales, which, on the Kanawha river, make up about one-fourth of the formation. From an economic standpoint this formation is of value and interest from the fact that it contains the great Pittsburg coal bed, which forms its base. Aside from the Pittsburg bed, the formation shows a number of beds that locally are of workable thickness.

The following four sections measured by I. C. White,[*] taken from the four principal counties in which it occurs will give a rather comprehensive view of the composition of the formation:

FAYETTE AND WESTMORELAND COUNTIES, PENNSYLVANIA.

	Feet.	Inches.
Coal, Waynesburg,	6	
Sandy shales or sandstone,	20	
Coal, Little Waynesburg,	2	
Limestone, Waynesburg,	20	
Shale and shaly sandstone,	50	

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[*] Bulletin 65, pp. 44-45.

FAYETTE AND WESTMORELAND COUNTIES—Continued.

Coal, Uniontown,	3	
Limestone, Uniontown,	12	
Sandstone,	30	
Limestone "Great,"	80	
Coal, Sewickley,	3	
Sandstone,	30	
Limestone, Sewickley,	25	
Shale or shaly sandstone,	20	
Coal, Redstone,	4	
Limestone, Redstone,	10	
Sandstone or shale,	40	
Coal, Pittsburgh,	12	
	367	

BROWNSVILLE, FAYETTE COUNTY, PENNSYLVANIA.

	Feet.	Inches.
Coal, Waynesburg, blossom,	..	
Shales, sandy,	45	
Coal, Little Waynesburg, blossom,	0	
Limestone, Waynesburg,	4	
Shales and shaly sandstone,	55	
Coal, Uniontown, blossom,	0	
Limestone, coarse, yellow,	1	
Clay,	3	
Shale and sandstone,	16	
Limestone,	2	
Concealed,	17	
Sandstone,	3	
Limestone with shales,	42	
Concealed,	16	
Limestone,	6	
Concealed,	7	
Clay shale,	8	
Sewickley coal horizon,	0	
Sandy shale and flaggy sandstone,	30	
Limestone,	30	
Shale,	35	
Coal, Redstone,	0	6
Shale, sandy,	25	
Coal, Pittsburgh: Coal, 0′ 8″; Clay, 0′ 10″; Coal, 7′ 6″,	9	
	354	6

WEST BROWNSVILLE, WASHINGTON COUNTY, PENNSYLVANIA.

	Feet.	Inches.
Coal, Waynesburg: Coal, 0′ 10″; Clay, 0′ 3″; Coal, 2′ 6″,	3	7
Shales and sandstone,	45	
Bituminous shale, Little Waynesburg coal,	1	6

WEST BROWNSVILLE, WASHINGTON COUNTY—Continued.

Limestone Waynesburg,	10	
Sandstone, shaly,	40	
Coal, Uniontown,	3	
Limestone, Uniontown,	12	
Shale and sandstone,	28	
Limestone, with thin shales,	88	
Coal, Sewickley, blossom,	0	
Sandstone, shaly,	32	
Limestone,	30	
Shales,	20	
Coal, Redstone,	1	
Sandstone and shales,	45	
Coal, Pittsburgh, roof: Coal, 0' 3"; Clay, 0' 3"; Coal, 1' 0"; Clay, 1' 0",	2	6
Coal, Pittsburgh, main bench,	7	0
Total,	368	7

RICE'S LANDING, GREENE COUNTY, PENNSYLVANIA.

	Feet.	Inches.
Waynesburg coal: Coal, 1' 0"; Clay, 0' 5"; Coal, 1' 3"; Clay, 1' 2"; Coal, 2' 6",	6	4
Shales,	40	
Limestone, Waynesburg,	6	
Shales and sandstone,	45	
Coal, Uniontown,	1	6
Limestone, Uniontown,	6	
Shales and sandstone,	38	
Limestone, "Great,"	82	
Coal, Sewickley,	1	9
Sandstone,	40	
Limestone,	25	
Sandy shale,	30	
Slate, bituminous (Redstone coal),	1	6
Sandstone, Pittsburgh, flaggy,	15	
Sandstone, Pittsburgh, massive,	30	
Coal, Pittsburgh, Roof: Coaly shale, 1' 0"; Coal, 1' 2"; Clay, 0' 10"; Main bench, 7' 0",	10	
Total,	378	1

CHARACTERISTIC MEMBERS.

Waynesburg Coal. This bed, which forms the top of the formation, is almost universally double, from 5 to 10 feet thick, one-fourth to one-half of which consists of clay partings.

Iron Ore. The shales underlying the Waynesburg coal sometimes contain much iron ore and nodules, which was at one time mined in Morgan township in Greene county.

Browntown Sandstone. In West Virginia a prominent, hard, gray, massive sandstone 20 to 35 feet thick occurs 5 to 10 feet below the Waynesburg coal.

Little Waynesburg Coal. A thin streak of coal or bituminous shale 1 foot or less thick occurs in Pennsylvania 25 to 40 feet below the Waynesburg coal.

Waynesburg Limestone. Directly below the last-named coal there is widely distributed a dark gray limestone 8 to 16 feet thick which disappears to the south. .

Uniontown Sandstone. At 60 to 75 feet below the Waynesburg coal very frequently occurs a massive gray sandstone.

Uniontown Coal. This coal lies 80 to 100 feet below the Waynesburg coal. In Fayette and Washington counties it is 3 feet thick, or less. Southward and southwestward it thins away to a mixutre of coal and black shale containing fish remains.

Benwood Limestone. Between the Uniontown and Sewickley coals 100 to 160 feet of the section is composed principally of limestone and limy shale. Sometimes it is almost solid limestone. More generally, however, it is made up of many limestone members separated by limy shale. Local names have been given to several of the more persistent benches or members.

Uniontown Limestone. The top, 10 to 15 feet, of the Benwood limestone is fairly well separated from the rest of the limestone below. It is an impure, buffish, magnesium limestone, suitable for the manufacture of natural cement. It appears to be the only limestone member of the Benwood limestone that reaches the Kanawha in West Virginia. In Washington county it is 30 to 40 feet thick, just below the Uniontown coal. Four layers of limestone with distinguishing characteristics may be described. The top bed is a brownish red limestone weathering soft and yellow. Its outcrop is usually marked by brown limestone nodules. One foot below this bed is a blue limestone weathering to a white clay, through which the blue shows. Sixteen to 18 feet lower is a limestone 1 foot thick, characteristically spotted. Ten feet under that is a solid limestone 1 foot thick containing hard particles that resist weathering, making raised, pimple-like protuberances on the weathered surface of the rocks.

Bulger Limestone. Separated from the last by 15 or 20 feet of coarse, calcareous shale, and about 60 feet above the Sewickley coal, is a limestone from 1 to 2 feet thick, of a solid to muddy brown color and uneven to smooth fracture. It is quite persistent and a good key horizon.*

Dinsmore Limestone. Below the Bulger limestone are 20 feet of shales, olive-green on top and red or yellow below. Under them are 4 feet of shales and limestones. The limestone is in beds 4 to 8 inches thick, of a creamy white color, separated by calcareous shale that weathers out and leaves the limestone ledges in bold relief. This limestone is the most persistent feature of this part of the Monongahela formation.

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*Bull. 318, p. 70, 1907.

Sewickley Sandstone. While there is frequently only limestone and shale between the Uniontown and Sewickley coals, in some places a flaggy to massive, often double, sandstone 20 to 60 feet thick occasionally appears just above the Sewickley coal, as at Big Falls on the Monongahela river.

Sewickley Coal (Meigs creek coal of Ohio and Mapleton coal of oil and gas drillers). Directly below the last-mentioned sandstone is the Sewickley coal. It is unimportant in northwestern Washington county, being only 4 to 8 inches, or less, thick, but increased to 5 or 6 feet in southeastern Greene county. In places it splits up until it occurs within a total space of 20 to 30 feet, often then appearing as two benches separated by up to 17 feet of sandstone. In a recent publication* J. J. Stevenson has assumed from a study of the sections and well records that this variation is due in part to the appearing and disappearing of coals at two different horizons, one of which he calls the Upper Sewickley, coming just above the Sewickley sandstone and under the Benwood limestone, the other coming under the Sewickley sandstone and just over the Fishpot limestone. Locally, the Sewickley sandstone between thins out, and they come together, as at Uniontown. While recognizing the possibility of such distinct horizons, the members of the U. S. Geological Survey in their recent work were not able to differentiate an Upper and Lower Sewickley coal. To the eastward in Maryland and to the westward in Ohio, two beds of coal appear to come between the Benwood limestone and the Redstone coal.

Fishpot (Sewickley) Limestone. From 40 to 60 feet down to the Redstone coal is usually occupied by a sandstone and one or two benches of limestone separated by shale. The limestone is often 20 to 30 feet thick. It has been called the Fishpot limestone.

From 118 to 142 feet above the floor of the Pittsburg coal the shaft sections in the Uniontown syncline show a coal that at no place reaches a greater thickness than 2 feet. This distance above the Pittsburg coal would correspond to that of the Sewickley coal in the basins further west, but it should be remembered that in the Uniontown syncline it is over 80 feet to the Redstone coal from the Pittsburg.

Redstone Coal. Thirty to 85 feet above the Pittsburg coal a small bed of coal is frequently found. It reaches 3 to 5 feet in thickness in parts of Fayette and Somerset counties. Recently it has been correlated as the Pomeroy bed of Ohio.*

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*Bull. Geological Society of America, vol. 18, pp. 35-37.

Redstone Limestone. Immediately under the Redstone coal is often found a limestone 10 to 20 feet thick. It is in great force around Wheeling, West Virginia, but disappears southward.

Pittsburg Sandstone. When the Redstone limestone is prominent it is usually underlain by shales down to the Pittsburg coal. When the limestone is thin or absent the Pittsburg coal is often overlain by a coarse, pliable, massive, often double, sandstone from 25 to 70 feet thick.

Pittsburg Coal. The Pittsburg coal is the best known, and at the present time the most valuable member of all the rocks in southwestern Pennsylvania. By carefully measuring the areas of the Pittsburg coal bed as shown on the maps accompanying Part I of the Annual Report of the Geological Survey of Pennsylvania for 1886, the Coal Report of the West Virginia Geological Survey, vol. II, 1904, and "The Coal Fields of Ohio," Geological Survey of Ohio, vol. VII, 1903, the following areas and tonnage of this bed in the three States mentioned is obtained:

	Area.	Thickness.	Est. Tonnage.
Pennsylvania,	2,126 sq. mi.	7 ft.	9,641,792,907
West Virginia,	2,609 sq. mi.	5 ft.	8,451,652,070
Ohio.	1,590 sq. mi.	5 ft.	5,150,668,835
			23,244,093,812

In the Pennsylvania part of this field the Pittsburg bed seems to be almost, if not quite, persistent. In parts of West Virginia and Ohio, the bed is thin or wanting. It appears to be true that the Pittsburg bed was, in part at least, laid down on an old, eroded surface. South of Pittsburg this is fairly evidenced in surface exposures, and more especially in the mines, the coal having been laid down on an irregular surface. Plate VI shows a small area in Allegheny county, south of Carnegie, and by structure contours the present position of the bottom of the Pittsburg coal. The original shape of the surface on which the Pittsburg bed was laid down could be obtained by taking the difference between the theoretical contour surface showing the structure due to folding by mountain-making forces, and the actual surface of the bottom of the coal. The non-conformity possibly shows again in the decreasing interval from the Pittsburg coal to the Ames limestone in going westward from Pittsburg. This interval, which is practically 300 feet at Pittsburg, decreases to 219 feet at Steubenville, Ohio, and to 150 feet in Guernsey county, Ohio.

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*Economic Geology, vol. 3, pp. 183-199, 1908.

The Pittsburg coal in its ordinary condition, as seen in most of Pennsylvania and Ohio, is double, showing the "roof" division, which varies from solid coal to laminations of coal and clay from 1 to 12 feet thick, separated by an "over"' clay of from a few inches to 2 feet from the "main" coal below. The "main" coal is again divided by thin clay partings into four benches called the "breast," "bearing in," "brick" and "bottom" coal. The different benches vary in character and quality. The "roof" coal is seldom worked.

In thickness the Pittsburg "main" bed averages about 7 feet in Pennsylvania, 5 feet in West Virginia and Ohio, and up to 22 feet in Maryland.

The bottom of the Pittsburg coal is usually taken as the bottom of the Monongahela formation. If, as now seems probable, there is an unconformity at the top of the Conemaugh formation, it would seem better to draw the formation boundary below the clay which underlies the Pittsburg coal, as that clay is found to be conformable with the coal, but not with the underlying formation.

CONEMAUGH FORMATION (OR LOWER BARREN MEASURES).

Thickness, Character and Extent. From 500 to 700 feet below the Pittsburg coal is found the Upper Freeport coal. The rocks between consist of shales, sandstones, conglomerates, limestones and thin coals. They are distinguished from the rocks above and below by the relative unimportance of the contained coals and by the abundant presence of red shales. The name Conemaugh (or Lower Barren Measures) has been applied to these rocks from the bottom of the Pittsburg coal to the top of the Upper Freeport coal. From Pittsburg southward this formation has a thickness of about 600 feet, increasing to the eastward and decreasing to the westward. West of Pittsburg the thickness decreases 50 feet within a few miles, and continuing across the Panhandle of West Virginia into Ohio, it becomes less than 500 feet and even down to 400 feet or less in southeastern Ohio.

The lower part of the formation is usually sandy. The middle or upper part is usually characterized by red and green shales. A number of thin limestones appear in the section and from 6 to 10 thin coals. Several of these coals are workable locally and more generally so in Maryland than in Pennsylvania.

Attention has already been called to the probable existence of a nonconformity of some moment at the top of the Conemaugh. Speaking of the top of the Conemaugh, I. C. White says "This interval, immediately below the Pittsburg coal for 30 to 40 feet, is more variable than any other portion of the Barrens, and, hence it is useless to try to classify its rocks." It is suspected that further study will show that in part at least this variability is due to the nonconformity, and that it will be found that the rocks immediately below the Pittsburg coal in the eastern part of the field have been removed further west. This variation is well displayed along the railroad track south from Carnegie. Thus, near Heidelburg, Allegheny county, a railroad cut shows the following section:

SECTION OF ROCKS UNDER PITTSBURG COAL NEAR HEIDELBURG, ALLEGHENY COUNTY.

Pittsburg coal, bottom of—	
1. Limestone, hard,	6 in. to 1 ft.
2. Shale,	2 "
3. Limestone yellow,	1′ to 1′ 3″
4. Shale, dark, with iron nodules near top,	8′
5. Limestone, upper 3′ well jointed,	3′
Lower 1′ Nodular,,	1′
6. Shale, with some sandstone,	10′
7. Limestone,	3′
8. Clay,	5′

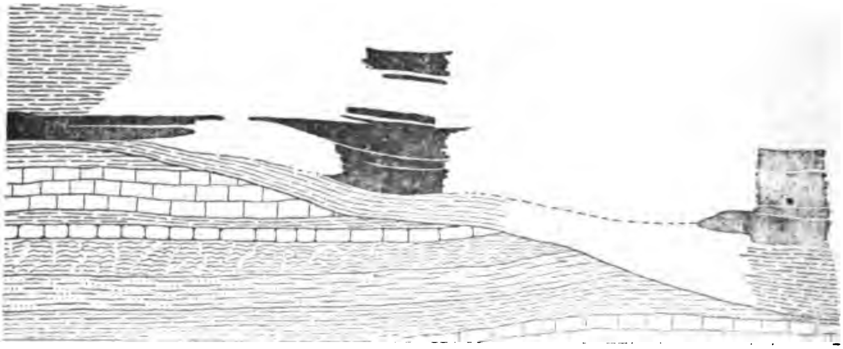

Fig. 14. Sketch showing nonconformity below Pittsburg coal as seen at Woodville, Allegheny county, (showing only actual exposures.) The coal at the left has been on fire and has been nearly burned out. Scale: 1 inch=20 feet nearly.

Directly across the tracks from the station at Woodville a sketch was made showing an unconformable contact between the clay under the Pittsburg coal and the underlying rocks (fig. 14), in which the edges of the limestone No. 5 of the section at Heidelburg can be clearly seen truncated by the pre-Pittsburg erosion, the clay under the coal descending until it rests on the lowest limestone bed, No. 7 of the section.

Frederick B. Peck appears to have been the first to observe this nonconformity as displayed from Carnegie to Woodside. A little further south, as revealed in the study of the mine maps by Mr. Martin, the Pittsburg coal occupies a northwest-southeast depression that at the time of the deposition of the coal must have been cut down to at least 40 to 60 feet below the adjoining level. The mine maps also show the general irregular character of the floor upon which the coal was laid down, as shown in plate VI. In fig. 15 are shown a series of sections of the Conemaugh formation ranging from east to west to show the increase in thickness in that direction, and general relation of the members and the variability in the composition.

In fig. 16 are given a number of short sections of the lower parts of the formation aligned on the top of the Upper Freeport coal to better show the composition and variability of that part of the formation.

It may add to the value of the sections in fig. 15 to describe the rocks in a few of those sections.

SECTION OF CONEMAUGH FORMATION IN PITTSBURG REGION.*

	Feet.	Inches.
Pittsburgh coal,	0	0
Concealed,	20	
Limestone,	2	
Shales, variegated,	65	
Limestone,	5	
Red shale,	20	
Concealed,	70	
Sandstone, Morgantown,	45	
Coal, Elk Lick,	1	
Shales, variegated,	50	
Coal,	2	
Limestone,	3	
Shales, variegated,	35	
Limestone, crinoidal,	2	
Coal, crinoidal (Hallem),	1	
Red and variegated shale,	30	
Sandy shales and shaly sandstone,	50	
Coal, Bakerstown,	3	
Shales and sandstone,	30	
Limestone, Upper Cambridge,	2	
Sandstone, massive,	50	
Limestone, Lower Cambridge,	1	
Shales,	10	
Coal, Masontown (Gallitzin), (Brush Creek),	1	
Shales,	20	
Sandstone, Mahoning,	100	
Upper Freeport coal,	0	
Total,	618	0

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*I. C. White, Bull. 65, p. 72. The writer questions the unity of the Mahoning sandstone, as it nowhere appears as a single sandstone stratum of that thickness that he is aware of.

SECTION OF CONEMAUGH FORMATION ON DUNBAR CREEK, FAYETTE COUNTY, PENNSYLVANIA.[*]

	Feet.	Inches.
Coal, Pittsburgh,	0	0
Concealed,	15	
Sandstone,	10	
Coal, Little Pittsburgh,		6
Clay,	3	
Limestone and shale,	20	
Sandstone, Connellsville,	60	
Shales,	50	
Limestone,	5	
Shale,	5	
Sandstone, Morgantown,	55	
Shale, sandy,	12	
Coal, Elk Lick,	1	
Shale,	12	
Concealed,	12	
Shale, variegated,	35	
Coal, clay, crinoidal,	2	
Shales, brown,	10	
Sandstone,	28	
Shale,	45	
Coal, Bakerstown,	2	
Shale,	63	
Limestone, Lower Cambridge,	3	
Shale,	7	
Sandstone, argillaceous,	10	
Concealed,	25	
Coal, Masontown,	2	
Clay,	30	
Sandstone, Upper Mahoning,	35	
Coal, Mahoning,	2	
Fire clay,	4	
Sandstone, Lower Mahoning,	35	
Coal, Upper Freeport,		
Total,	598	6

SECTION OF CONEMAUGH FORMATION AT LIGONIER, WESTMORELAND COUNTY, PENNSYLVANIA.[†]

	Feet.	Inches.
Pittsburgh coal,		
Concealed,	60	
Coal, Little Pittsburgh,	1	6
Limestone,	8	
Concealed,	27	
Shale, variegated,	43	
Coal, Little Clarksburg,	1	6
Shale,	10	

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[*] J. J. Stevenson, Geological Survey of Pennsylvania, Report KK, p. 182.
[†] J. J. Stevenson, 2d Pennsylvania Survey, Report KKK, p. 129.

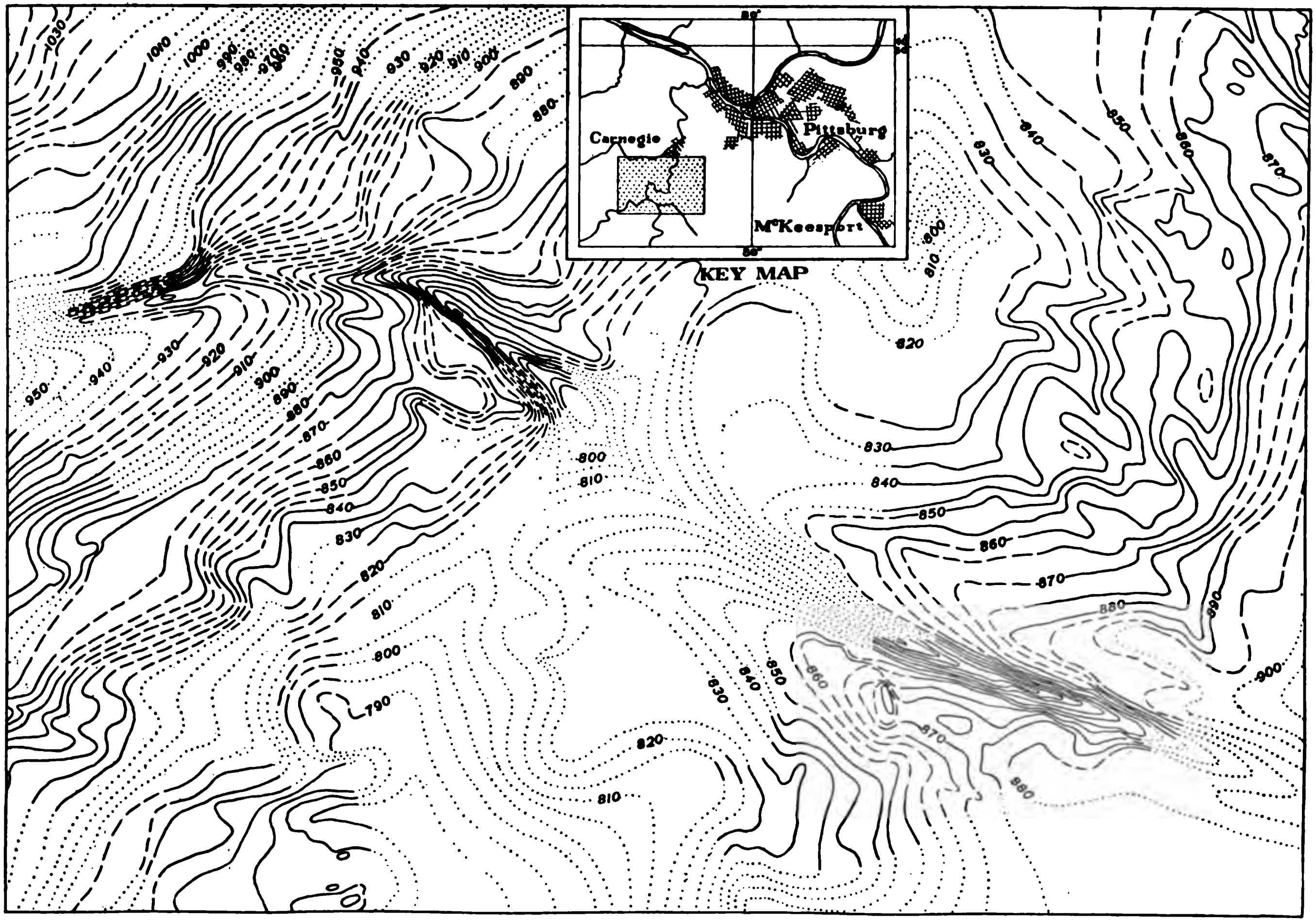

Plate VI. Sketch map showing by 5-foot contours the structure or "lay" of the base of the Pittsburg coal south of Carnegie. Solid and broken lines from detailed mine maps based on spirit level elevations; dotted lines from drillings and surface geology. Horizontal scale: 1 inch=4,000 feet; contour interval 5 feet.

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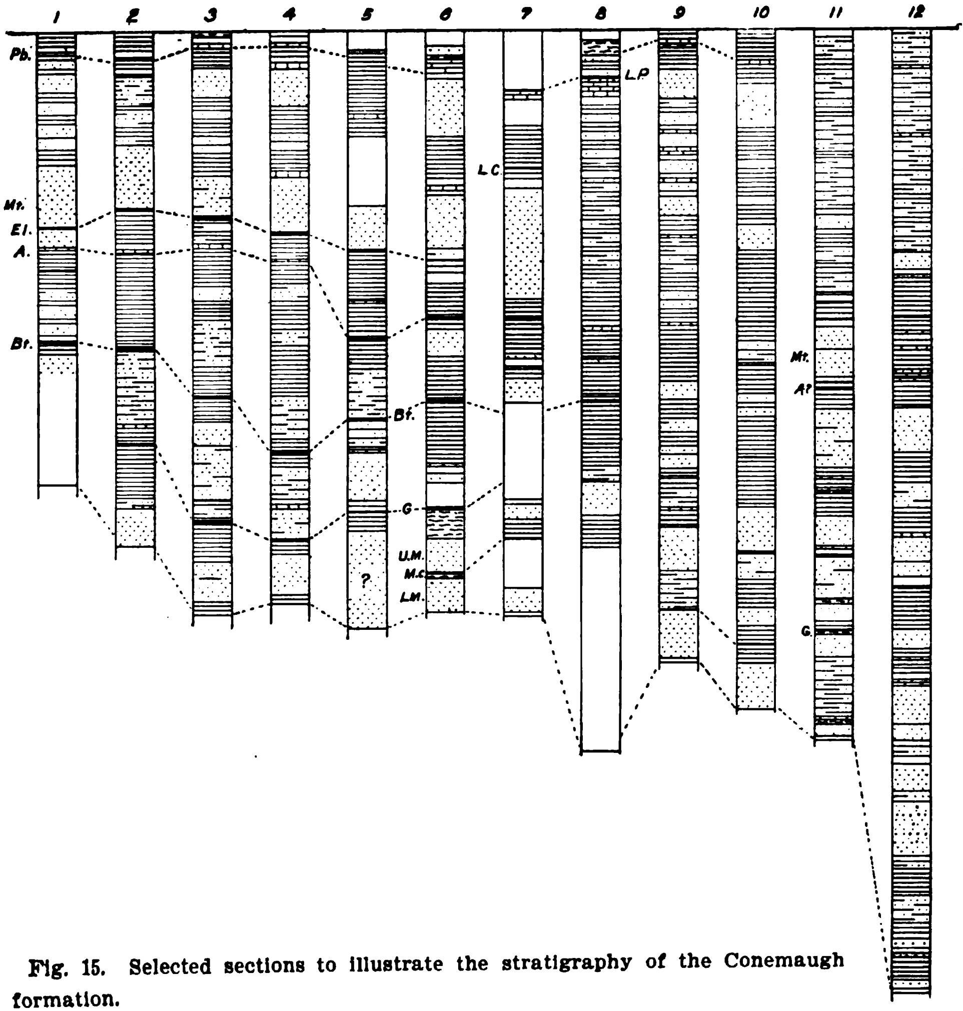

Fig. 15. Selected sections to illustrate the stratigraphy of the Conemaugh formation.

(Note: A comparison of these sections with the generalized sections in the folios from which many of them have been taken, will show that as a rule the sandstones, limestones and coals here shown are in the original sections represented as only found in part of the area. This makes the formation appear to contain much more sandstone than it should).

1. Steubenville (I. C. W. and W. T. Griswold).

2. Generalized section from Beaver quadrangle (L. H. W., U. S. G. S., Folio 134).

3. Generalized section from Brownsville-Connellsville quadrangles. (M. R. C., U. S. G. S. Folio 94).

4. Generalized section from Masontown-Uniontown quadrangles, (M. R. C., U. S. G. S. Folio, 84).

5. Pittsburg region. (I. C. W., U. S. G. S. Bull. 65, p. 72).

6. Dunbar Creek, Fayette county.

7. Ligonier, Westmoreland county, (J. J. S., Second Geol. Survey of Pa., Rept. KKK, p. 129).

8. Section of Saxman salt well near Latrobe, (M. R. C., U. S. G. S. Folio 110, p. 8).

9. Generalized section for Elders Ridge quadrangle, (R. W. S., U. S. G. S. Folio 123).

10. Generalized section for Indiana quadrangle, (G. B. R., U. S. G. S. Folio 102).

11. Generalized section, Barnesboro-Patton quadrangles.

12. Wilmore basin, Cambria county.

Pb., Pittsburg limestone; L. P., Little Pittsburg coal; L. C., Little Clarksburg coal; Mt., Morgantown sandstone; El., Elklick coal; A, Ames limestone; Bt., Bakerstown coal; G, Gallitzin coal; U. M., Upper Mahoning sandstone; M. c., Mahoning coal group; L. M., Lower Mahoning sandstone.

Vertical scale: 1 inch=200 feet.

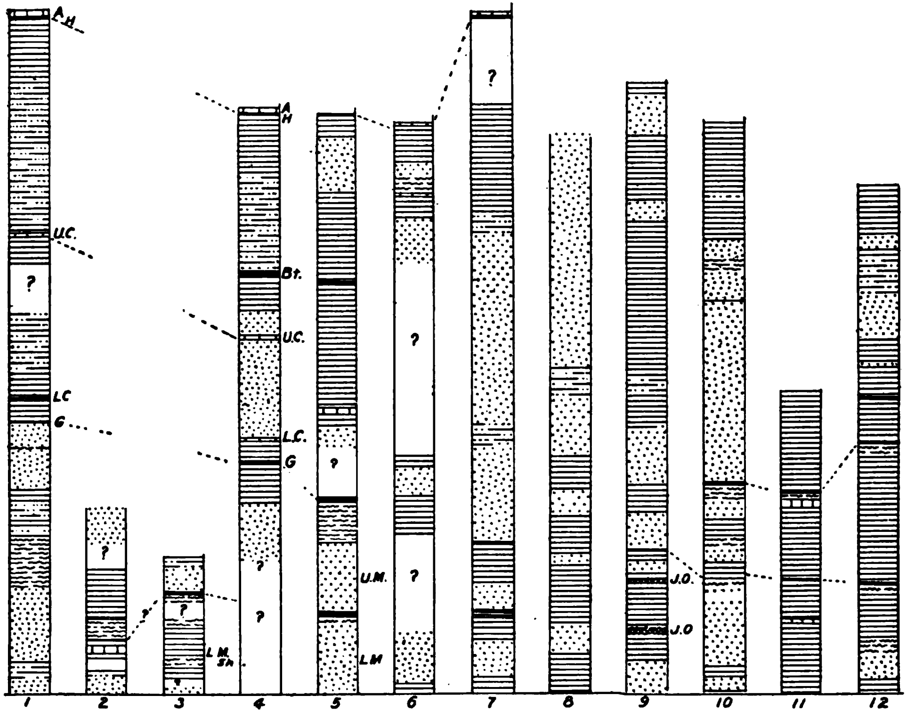

Fig. 16. Selected section from lower half of Conemaugh formation, aligned on the top of the Upper Freeport Coal. To show the composition of that part of the section.

1. Diamond drilling at Sewickley (I. C. W., U. S. G. S. Bull. 65, p. 73).

2. Section near Bellowsville, Beaver Co. (L. H. W., U. S. G. S. Bull. 286, p. 10).

3. Section on Six-mile Run, Beaver Co. (L. H. W., U. S. G. S. Bull. 286, p. 10).

4. General section in the Pittsburg region (I. C. W., U. S. G. S. Bull. 65, p. 72).

5. Dunbar Creek section (J. J. S., Second Geol. Survey of Pa., Rept. KK, p. 182).

6. Section at Ligonier, Westmoreland Co. (J. J. S. Second Geol. Survey of Pa. Rept. KKK, p. 129).

7. Armstrong county (compiled) (W. G. Platt, Second Geol. Survey of Pa., Rept. H5, p. 5).

8. Section near Saltzburg, (M. R. C., U. S. G. S. Folio 110, p. 8).

9. Johnstown section (John Fulton, Second Geol. Survey of Pa., Summary Rept., p. 2412).

10. Cresson shaft (Cresson Coal and Coke Company) (Second Geol. Survey of Pa., Summary Rept. p. 2412).

11. Diamond drilling, Northeast Cambria county.

12. Diamond drilling, Northwest Cambria county.

A, Ames limestone; H, Harlem coal; Bt, Bakerstown coal; U. C., Upper Cambridge limestone; L. C., Lower Cambridge limestone; G, Gallitzin coal; U. M., Upper Mahoning sandstone; Mc, Mahoning coal, clay and limestones; J. O.; Johnstown ore horizon; L. M., Lower Mahoning sandstone; L. M. sh., Lower Mahoning flinty shale.

Scale: 1 inch=100 feet.

	Feet.	Inches.
Concealed,	10	
Sandstone, Morgantown,	115	
Shale, olive,	18	
Coal, Elk Lick,	3	6
Shale,	15	
Limestone, green, fossiliferous,	0	0
Shale,	20	
Sandstone,	5	
Clay,	8	
Limestone, ferruginous,	2	
Shale,	10	
Sandstone,	25	
Concealed,	100	
Shale,	5	
Sandstone, Upper Mahoning,	15	
Shale,	20	
Coal, blossom, Mahoning,	..	•
Concealed,	50	
Sandstone, Lower Mahoning,	25	
Shale,	5	
Coal, Upper Freeport.		
Total,	602	6

SECTION OF CONEMAUGH FORMATION NEAR BERLIN, SOMERSET COUNTY, PENNSYLVANIA.*

	Feet.	Inches.
Pittsburg coal,	..	-
Interval, shales, sandstones, etc.,	200	
Coal,	1	
Limestone, gray and buff,	10	
Concealed,	50	
Sandstone, massive,	25	
Shales, dark,	15	
Coal, Platt (crinoidal): Cannel shale, 1′; Coal, shaly, 2′; Shale, 1′; Coal, 3′,	7	
Sandy shales and black slates,	50	
Coal, Price (Bakerstown): Coal, 3′ 2″; Shale, 0′ 4″; Coal, 0′ 6″,	4	
Shales, dark,	4	
Limestone, dark gray: Limestone, 1′ 8″; Shale, 0′ 8″; Limestone, 1′ 4″,	3	8
Shale,	..	6
Coal,	1	6
Shales, and concealed,	45	
Coal, Coleman,	1	6
Shale, dark,	..	2
Limestone, Coleman (Upper Cambridge),	1	
Shales,	10	
Sandstone, and concealed,	15	

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*Platte & White.

	Feet.	Inches.
Shales, sandy,	15	
Coal, Philson: Coal, 1′ 3″; Shale, black, 0′ 9″; Coal, 0′ 6″,	2	6
Fire clay,	2	
Limestone, Philson (Lower Cambridge): Limestone, dark, 1′ 0″; Shale, black, 0′ 4″; Limestone, 2′ 0″,	3	4
Concealed, and shales,	25	
Coal, Masontown,	2	
Concealed,	5	
Sandstone, Mahoning, and concealed,	100	
Coal, Upper Freeport.		
Total,	599	2

CHARACTERISTIC MEMBERS.

Pittsburg Coal Iron Ores. In Fayette county a group of iron ores come immediately below the Pittsburg coal and have been mined for the manufacture of iron for 75 years or more. These ores are confined principally to the Blairsville Basin. They appear to replace ferruginous limestone at other places.

Little Pittsburg Coal. From 25 to 60 feet below the Pittsburg coal is a thin, persistent coal bed, usually only 1 to 2 feet thick. In Somerset county and in Maryland there frequently appear to be two Little Pittsburg coals occurring above and below the Upper Pittsburg limestone. Occasionally they are 3 or 4 feet thick locally.

Pittsburg Limestones. The section near Heidelburg, given on a preceding page, shows 4 limestones close below the Pittsburg coal. Limestones have been widely noted within a shale interval of 50 to 75 feet below the Pittsburg coal, and it has generally been assumed that there were two more or less regular horizons known as the Upper and Lower Pittsburg limestones. The section just referred to shows that the Upper Pittsburg limestone may be any one of several limestones just under the Pittsburg coal. From this it may be assumed that the part in question, the Upper Pittsburg limestone, has split up. The Upper limestone as found is usually only from 3 to 5 feet thick, while the Lower is sometimes much thicker and purer.

Connellsville Sandstone. A massive, fine, conglomeritic sandstone frequently comes a short distance below the Pittsburg limestone. It is often a cliff maker. It is more prominent in Maryland and West Virginia than in Pennsylvania. Its top is from 40 to 60 feet below the Pittsburg coal.

Little Clarksburg Coal. One hundred to 125 feet below the Pittsburg coal, and close under the Connellsville sandstone, is a thin bed of shaly coal. It is usually not over 1 to 2 feet thick, but in Somerset county and in Maryland becomes 6 feet thick, or more. It usually remains shaly or has a high ash. It is probably this coal that reaches a thickness of 5 or 6 feet in local spots around Barington, Washington county.

Clarksburg Limestone. Just under the Little Clarksburg coal often occurs a limestone characteristically filled with ostracoids and fish remains. It is 3 to 9 feet thick and up to 30 feet thick. Some of it is ferruginous enough to have been mined at one time for iron.

Morgantown Sandstone. This sandstone is one of the most persistent members of the Conemaugh. It is often a cliff maker and nearly everywhere is suitable for quarrying. It is from 25 to 50 feet thick, and its top comes 200 feet below the Pittsburg coal.

Elk Lick Coal. Immediately below the Morgantown sandstone a thin coal is reported to have a wide extent. In Westmoreland, Fayette and Allegheny counties it is persistent, but usually under 2 feet thick. In Somerset county it reaches a thickness of 4 feet and has been mined locally.

Elk Lick Limestone. In Somerset county a limestone 12 feet or less in thickness occurs a short distance below the Elk Lick coal. It does not appear to be persistent to the westward.

The Ames or Crinoidal Limestone. This, as stated elsewhere, is one of the great key horizons. Though a relatively thin limestone, rarely more than 2 feet, it appears to have been very widely deposited, and in general to have characteristics that render its recognition easy and certain. Prof. Stevenson describes it as: "Dark bluish or greenish gray, tough, and breaks with a granular surface which resembles that of coarse sandstone. * * * In all cases it is fossiliferous and contains immense numbers of crinoidal stems and spines or plates." A recent detailed work in the Sewickley quadrangle Mr. Munn has noted one or two limestones between the Ames and the Bakerstown coal. These resemble the Ames so closely that he has had to depend on the association with the Ames of the yellow shale in which it lies and the red shale below to distinguish them. It is the highest limestone in the coal measures containing marine fossils. It comes almost exactly half way from the Pittsburg coal to the Upper Freeport coal. It has been recognized over much of southwestern Pennsylvania, over eastern Ohio, in northeastern Kentucky, and in northwestern and southwestern West Virginia. Its distance below the Pittsburg coal at Steubenville is 219 feet, determined as the average of many spirit leveled measurements. Near Coraopolis similar measurements give 230 feet, and near Allegheny City 280 feet. This interval with slight increase it holds to the east and south. Its distance above the Upper Freeport coal in Pennsylvania is from 300 to 350 feet. When the limestone is absent its position is often marked by the presence of the fossiliferous beds which ordinarily accompany it.

Harlem (Friendsville or Crinoidal) Coal. Close below the Ames limestone is a thin coal, usually not over 8 inches thick. It appears to be workable in the Berlin Basin of Somerset county, and in a few other places.

Pittsburg Red Shales. Through most of Pittsburg and West Virginia the Ames limestone is underlain by a considerable thickness of red shale. These shales when wet produce a sticky red mud on the surface and cave in oil wells, making it necessary to case through them. This is probably the thickest and most widespread group of red shales occurring in the Conemaugh. They are described by I. C. White as making a broad red band along their outcrop through West Virginia.

Saltsburg Sandstone. The name Saltsburg sandstone was originally applied to the great body of sandstone outcropping opposite Saltsburg on the Kiskiminetis river. It is there 120 feet thick, and its top is 285 feet above the Upper Freeport coal. The sandstone here appears to be somewhat anomalous, and it seems quite possible that the unusual thickness is due to the local union of two sandstones, the Buffalo sandstone below, and what has sometimes been called the First Cow Run sand of the oil drillers. Such cases of two sandstones pinching out the intervening strata and running together are not uncommon. Between these sandstones is ordinarily the Bakerstown coal with the associated red shale, limestone, et cetera. G. C. Martin, in his report on the coal measures of Maryland, uses the name Saltsburg for the sandstones above the Bakerstown coal. Apparently a similar condition exists in the western part of the Kittanning quadrangle, where there are 40 to 50 feet of sandstone below the Bakerstown coal and 60 to 80 feet of sandstone above the two sandstones, being separated by the thin interval of shale containing the coal, though this separation is often not observable.

Bakerstown Coal. Seventy-five to 90 feet below the Ames limestone is found the Bakerstown coal, so named from its occurrence at Bakerstown in northern Allegheny county. It comes from 175 to 220 feet or more above the Upper Freeport coal. Though generally thin, this bed reaches a mineable thickness in places, and is mined in a few places commercially. It has a thickness of up to 5 feet.

Lower Red Shales. Below this coal red shale is found rather persistently as far east as the northeast corner of Indiana county or beyond.

Upper Cambridge Limestone. Associated with these red shales is often found a thin limestone. Sometimes apparently there is more than one. It is quite possible that these limestones are not persistent. They appear to occupy the position of the Upper Cambridge limestone of Ohio.

Buffalo Creek Sandstone. In the region of Buffalo creek in Butler county, and following down the Allegheny river, there is a prominent sandstone that occupies the stratigraphic position between the Gallitzin (Brush creek) and Bakerstown coals. In southeastern Jefferson and northwestern Indiana counties and in much of the country to the east, is a notable shaly interval. The shales showing in the railroad cuts all about Punxsutawney and Lindsey come at this horizon. They occupy practically the whole interval between the Gallitzin (Brush creek) and Bakerstown coals, except for the red shale at the top. In Ohio this interval is usually occupied by shale.

Lower Cambridge Limestone. From 90 to 130 feet above the Upper Freeport coal is a limestone that is characteristically dark, often black, and usually very full of marine fossils. It is usually associated with black shales and underlain by a coal bed. If the correlation has been correctly made, this is one of the most widespread members of the Appalachian Coal Measures. It would appear to be traceable from the Allegheny front across Pennsylvania and Ohio into northeastern Kentucky. This wide correlation is not altogether certain, and the limestone has not proven as valuable a key horizon by far as the Ames limestone. As the Upper Cambridge limestone is often dark and contains the same fossils as the Lower, they are often confused.

Gallitzin Coal. The Gallitzin coal has passed under a variety of names. Gallitzin, Brush Creek, Masontown and Farmington, are among the many names that have been used for apparently this same coal. It appears to have been first described and its position accurately determined at the tunnel at Gallitzin, in volume HH of the Second Pennsylvania Survey, but was not named in that volume. It was recognized as above the Upper Freeport coal, and supposed at that time to be the first coal above, as it is at that point. In volume HHH, page 293, the first coal above the Upper Freeport is called "the Gallitzin coal," though in the section where it appears, it is applied to the first coal above the Upper Freeport, which in this case is at the horizon of the Mahoning coal. It was recognized at that time as occupying the same stratigraphic position as the Brush creek coal, which I. C. White had then seen but not described. As to the matter of publication, the two reports HHH and Q bear the same date of publication, though the field work for volumes HH and HHH preceded that for volume Q. As the type locality Gallitzin has the distinct advantage that the shaft section at that town gives accurately the position of the Gallitzin coal in relation to the Upper Freeport coal, while at Brush creek the exact distance of the Brush creek coal to the Upper Freeport coal is still quite uncertain, the term Gallitzin has here been adopted for general use. In report Q Dr. White describes the Brush creek coal as 75 feet above the Upper Freeport. In his recent volume on coal for the West Virginia Geological Survey (volume 2, page 304, 1903), he says: "* * * but subsequent investigation revealed the fact that the coal along Brush creek lies more than 100 feet above the base of the Conemaugh, and is the second coal above the Upper Freeport seam instead of the first, so that the name 'Brush Creek' having been given under a misapprehension, has to be dropped." The Gallitzin coal is almost if not quite as persistent as the Lower Cambridge limestone. The fact that the coal here occurs under the limestone distinguishes it from the Mahoning coal or the coals of the Allegheny formation, where with the local exception of the Vanport, in all cases of association of the coals and limestones the coal is above the limestone. The coal occurs from 90 to 130 feet above the Upper Freeport coal, the interval at Gallitzin of 110 feet being about the average.

Mahoning Sandstone Group. The limestones and composition of the Mahoning sandstone group has been a matter of some question in the past, but there has come to be substantial agreement that any sandstone between the horizons of the Upper Freeport coal and the Gallitzin coal belongs in the Mahoning group. Notwithstanding that this is always thought of as a sandstone group, possibly the most persistent member of it is a clay. This has been designated the Thornton fireclay by I. C. White, from Thornton, Taylor county, West Virginia, where it is extensively mined and shipped. Examination of drillings and sections of this part of the Conemaugh almost always shows the presence of a clay 40 to 60 feet above the Upper Freeport, though often absent. Over this clay is frequently found a small coal bed, and under it a limestone, usually ferruginous, sometimes grading over into an iron ore (the Johnstown ore horizon of the Second Survey). There is also frequently a little red shale at this horizon. This is apparently the lowest horizon in Pennsylvania at which red shale occurs in the coal measures. The spaces above and below this coal group of coals, limestones, iron ores, and clay, may be filled with sandstone or with shale, clay, et cetera. It is only locally that both spaces are filled with massive sandstone, though quite commonly one or the other is filled with a massive coarse-grained, often gritty sandstone. The exact type locality of the Mahoning group is not now known, but it is supposed to have been some portion of the valley of Mahoning creek. On Mahoning creek, in southeast Jefferson county, as well as in northeastern Indiana county and at least the southern half of Clearfield county, the interval below the Mahoning coal usually contains little or no sandstone, but instead 40 to 60 feet of shale more than usually free from sand. In the same region the space above the Mahoning coal frequently contains a hard massive conglomerate, as may be seen occupying the Chestnut Ridge anticline near the corner of the three counties mentioned. In that region, in the shale interval below the Mahoning coal there is frequently found a portion of the shale that is very fine-grained and tends to grade over into a flint clay, occasionally becoming a fair grade of clay, though usually too ferruginous. This condition is well illustrated by two sections, the first taken from above the tunnel south of Moxham, on the Johnstown quadrangle, and the second from a new cut on the Buffalo, Rochester and Pittsburg R. R., close to Williams station east of Punxsutawney. Both sections were hand leveled by the writer.

SECTION ABOVE TUNNEL SOUTH OF MOXHAM NEAR JOHNSTOWN, PA.

	Feet.	Inches.
Sandstone, thin and cross-bedded (Upper Mahoning),	8	
Shale, brown,	2	
Coal, Mahoning: Coal, 0′ 3″; Shale, dark drab to black sand, 2′ 0″; Coal, 0′ 7″,	2	10
Clay, hard,	..	6-8
Limestone, ferruginous (Johnstown ore horizon),	1	6
Clay, drab,	1	
Hidden; probably gray shale,	15	
Clay; some a yellow flint clay,	10	
Sandstone, brown and gray, massive,	20	
Shale, brown, sandy,	7	
Coal, Upper Freeport: Coal, 3′ 3″; Parting thin coal and clay in bands, 0′ 7″,	3	10
Clay, light drab,	4	
Clay, hard, gnarly, changing to sandstone below,	4	
	79	10

SECTION AT WINSLOW STATION, BUFFALO, ROCHESTER & PITTSBURG R. R., EAST OF PUNXSUTAWNEY.

	Feet.	Inches.
Sandstone, brown, shaly,	6	
Shale, light-drab,		6
Shale, black (place of Mahoning coal),		1
Clay, olive drab,	2	
Shale, deep chocolate and olive (fairly typical red shale),	4	
Limestone, highly ferruginous (much of it calcareous iron ore) (Johnstown ore horizon),	4	
Shale, olive, very fine-grained,	23	
Shale, black,		1
Clay, olive-drab, hard,		6
Clay, dark-drab,		10
Clay, olive-drab,	2	
Shale, olive, sandy, grading into olive sandstone below,	10	
To railroad track.		
	52	11

This clay is generally distinguishable from the flint clays of the underlying Allegheny formation by its rusty olive-yellow color. In Lawrence and Beaver counties there occurs a very similar clay, but there it is thought to come above the Mahoning coal. In the western part of the coal field it is more usually the lower space that is filled with sandstone, which there quite often becomes very massive and coarse-grained. The variableness of these sandstones has not been fully recognized in the past and many errors of correlation have resulted from their misinterpretation. As is brought out under the heading of coal, the base of the Lower Mahoning sandstones rests on a slightly eroded surface. It is usually separated from the coal by a few feet of shale, variable in thickness and often cut out. When the sandstone rests on the coal it is found to displace the top of the coal bed irregularly and often the whole bed has been removed.

ALLEGHENY FORMATION.

GENERAL CHARACTER AND THICKNESS.

This formation, which was originally known as the Lower Productive Coal Measures, yields about 40 per cent. of the bituminous coal mined in Pennsylvania. It forms a broad but irregular belt or fringe around the coal field in Pennsylvania, and is brought up well within the coal field by the prominent anticlines. It is usually distinguished from the Conemaugh formation above mainly by the presence in it of several workable coal beds, and from the underlying formation by the smaller amount of sandstone that it contains. It has often been delimited as occurring below the massive Mahoning sandstone and above the massive Homewood sandstone. As has already been brought out, the Mahoning is not always a massive sandstone, particularly in its lower half, and in many places what has been considered the Homewood sandstone would now appear to be the Clarion, occurring within the formation, so that these distinctions and delimiting factors are not sharp, and in themselves are only suggestive. Thus it frequently happens that the erosion that closely followed the laying down of the Upper Freeport coal, the uppermost coal in the formation, has removed that coal or rendered it thin and irregular, and in same cases both of the Freeport coals are thin or lacking. Under these conditions the presence or absence of thick coals may not be used as a factor to determine the limits of the formation.

The formation has a thickness of about 300 feet. It is believed to become thinner to the south in West Virginia, and it shows a large increase in the number of coals contained, if not in general thickness, toward the northeast, though apparently this gain does not hold as far east as Blossburg Basin, in Tioga county, where the formation is reported as only 150 to 160 feet thick.

In studying the stratigraphy of the Allegheny formation it may be well as far as possible to first examine the sections at the type localities, beginning at Freeport.

SECTION AT FREEPORT. I. C. W., U. S. GEOL. SURVEY BULL. 65, p 111.

	Feet.	Inches.
1. Coal: Upper Freeport,	3	9½
2. Clay,	1	6
3. Limestone, Upper Freeport,	3	6
4. Shale, sandy,	20	

			Feet.	Inches.
5. Coal; "Middle Freeport," Lower Freeport,			2	
6. Shale, sandy, and sandstone,			39	
7. Coal, "Lower Freeport,"				
	Feet.	Inches.		
Cannel shale,	5			
Coal, shaly,	4			
Clay with limestone,	2	6		
Coal, shaly,	2	6		
	——	——	14	
8. Clay and shale,			2	
9. Sandstone, massive,			45	
10. Coaly shale; "Upper Kittanning,"			0-4	
11. Sandstone, gray, massive,			15	
12. Coal; "Middle Kittanning,"			1	6
13. Clay with limestone nodules,			6	

The 2 feet of coal 25 feet below the Upper Freeport has usually been called the Middle Freeport, and the coal 66 feet below the Upper Freeport called the Lower Freeport. It is of no small interest that nowhere else has the Middle Freeport been definitely recognized. Examined more closely it will be noted that below the Upper Freeport coal is a limestone, and between the limestone and the so-called Middle Freeport coal was laid down 20 feet of sandy shale. Going up the Allegheny river a few miles a good section of the rocks can be seen opposite Logansport. I. C. White has measured a section as follows:

SECTION OPPOSITE LOGANSPORT, ARMSTRONG CO., PA., I. C. W., U. S. GEOL. SURVEY BULL. 65, p. 110.

			Feet.	Inches.
1. Coal; Upper Freeport,			3	
2. Clay,			4	
3. Limestone in layers with shale partings,			14	
4. Shale and clay,			10	
5. Coal; Lower Freeport:				
	Feet.	Inches.		
Coal,	2			
Clay,	2	4		
Coal,	4	8		
	——	——	9	
6. Hidden,			11	
7. Sandstone, very massive, gray to white, pebbly,			70	
8. Coal; Upper Kittanning,				8
9. Shale, dark-gray,			20	
10. Coal; Middle Kittanning:				
	Feet.	Inches.		
Coal,		8		
Shale,		2		
Coal,		6		
	——	——	1	4

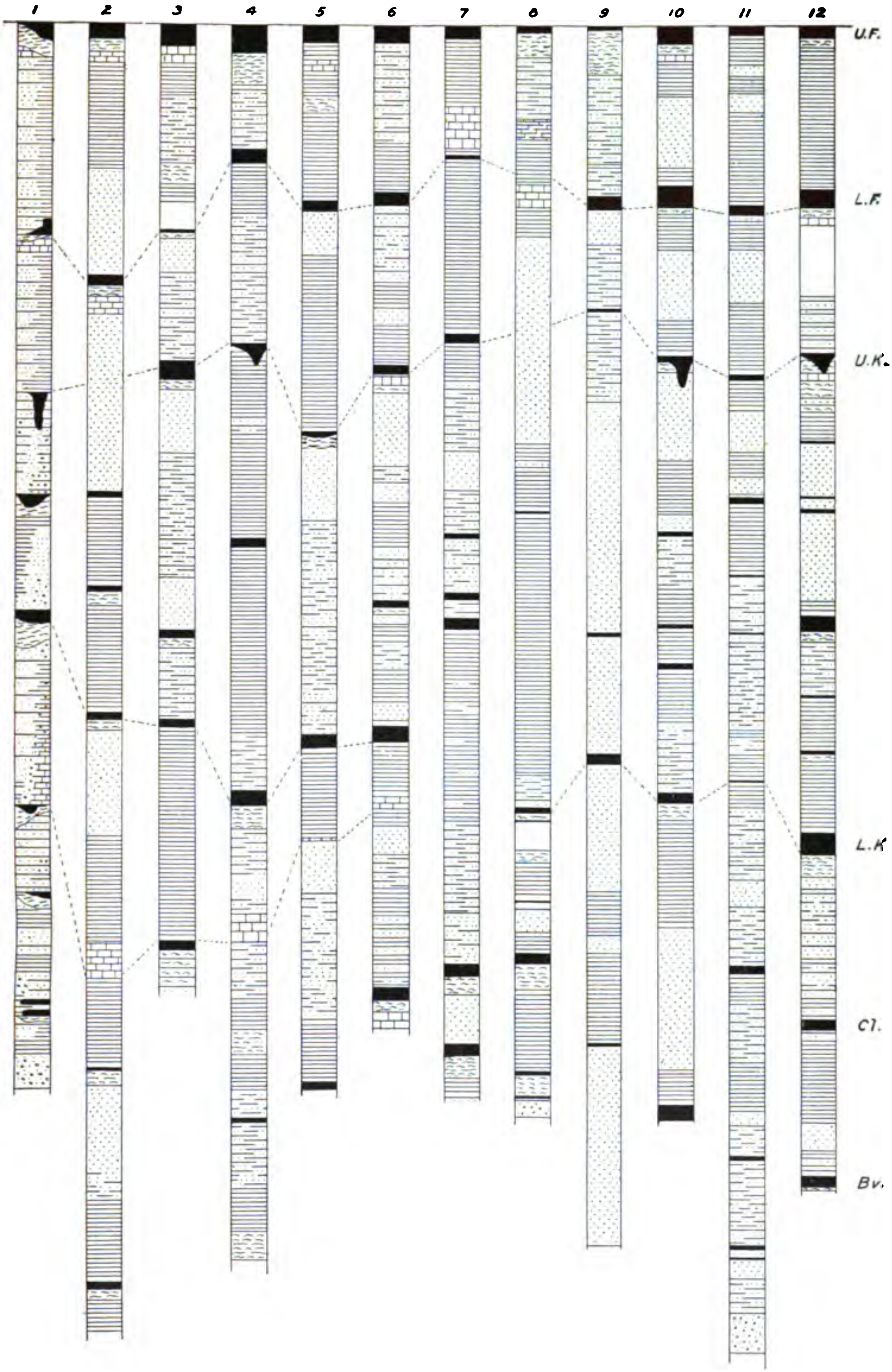

Fig. 17. Selected sections to illustrate the stratigraphy of the Allegheny formation in Western Pennsylvania.

1. Generalized section, Newcastle quadrangle. 2. Generalized section, Beaver quadrangle. 3. Section on Cucumber creek, Uniontown quadrangle. 4. Generalized section, Kittanning-Rural Valley quadrangles. 5. Selected section, Indiana quadrangle. 6. Selected section, Johnstown quadrangle. 7. Generalized section, Ebensburg quadrangle. 8. Selected section, Barnesboro quadrangle. 9. Selected section, Patton quadrangle. 10. Generalized section, Punxsutawney quadrangle. 11. Selected section, Curwensville quadrangle. 12. Generalized section, Houtzdale quadrangle.

U. F., Upper Freeport; L. F., Lower Freeport; U. K., Upper Kittanning; M. K., Middle Kittanning; L. K., Lower Kittanning; V. P., Vanport Limestone; Cl., Clarion; Br., Brookville.

Vertical Scale: 1 inch = 50 feet.

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	Feet.	Inches.
11. Clay,	1	
12. Limestone,	1	
13. Clay with limestone nodules in top,	8	
14. Sandstone, shaly,	7	
15. Hidden; probably shale,	15	
16. Shale; blue,	20	
17. Coal; Lower Kittanning,	3	6
18. Hidden to river,	20	
19. Estimated to bottom of Allegheny formation,	80	
	298	6

The 9-foot coal in this section has been considered the Lower Freeport without question, yet notice that only 10 feet of shale and clay was laid down on top of the coal before the limestone was laid down. While it can not be asserted that the limestones in the two places were laid down simultaneously, considering the wide-spread occurrence of a limestone just below the Upper Freeport coal all through Pennsylvania, it will generally be conceded that they were laid down at practically the same time, but considering that 20 feet of shale was being laid down at Freeport while only 10 feet was being laid down at Logansport, it looks as though the first coal from the top at Freeport must be the same as the first coal from the top at Logansport, *or else a lower coal.* The first premise is preferable. Without carrying the argument further, and without asserting that the first coal below the Upper Freeport through the State generally is the same as the first coal below the Upper Freeport at Freeport, the evidence strongly suggests that the coal at 25 feet below the Upper Freeport at Freeport and not the one at 66 feet, is the coal that corresponds most nearly with the horizon of the so-called Lower Freeport coal over the State. The question then arises, which should be changed, the name of the second coal at the type locality, or the name of the second coal in the Allegheny throughout the State? The practical solution is to call the second coal at Freeport the Lower Freeport. What then is the third coal? The presence of the cannelly shale suggests the Upper Kittanning. Until the section below drainage at Freeport is known, it may be difficult to answer the question satisfactorily.

Some of the difficulties of proving correlations may be realized by comparing the section at Logansport with one two miles farther up the river, and one mile below the mouth of Crooked creek. This was carefully leveled by I. C. White, and gave as follows:

SECTION 5 MILES BELOW KITTANNING. I. C. W. U. S. GEOL. SURVEY BULL. 65, p. 109.

	Feet.	Inches.	Feet.	Inches.
1. Coal; Upper Freeport; blossom.				
2. Clay,			2	6
3. Sandstone,			2	6
4. Clay and shale,			5	
5. Hidden,			5	
6. Limestone,			10	
7. Hidden,			35	
8. Shale, bluish,			20	
9. Coal; Lower Freeport:				
Coal,		2		
Shale,	1	8		
Coal,	1	8		
			3	6
10. Clay and shale,			10	
11. Sandstone, massive, pebbly,			45	
12. Coal; Upper Kittanning,				6
13. Shale, drab,			20	
14. Coal, shaly in middle; Middle Kittanning,			1	6
15. Limestone, sandy,			1	6
16. Clay,			3	
17. Sandstone, flaggy,			3	
18. Clay,			5	
19. Sandstone, flaggy,			8	
20. Shale, dark,			10	
Total,			191	

Here the so-called Lower Freeport is 80 feet below the Upper Freeport, yet if the strata Nos. 8 to 18 of this section be compared with Nos. 4 to 15 of the Logansport section, it will be seen that almost the only difference is in the thickness of the massive conglomerate, in one case 70 feet, in the other 45. That those parts of the two sections describe the same rocks will hardly be questioned. The thinning of the conglomerate is to be expected. Conglomerates are characteristically local and irregular in thickness. That 10 feet of shale at Logansport should thicken up to 55 feet in 2 miles is not so commonly expected, notwithstanding it is a matter of weekly if not daily occurrence in studying the stratigraphy of the Pennsylvania coal measures. See fig 9, where is shown a case near Curwensville, in which 10 feet of shale near the New York Central depot can be seen thickening up to 30 feet or over in the bare face of the cut in the space of a quarter of a mile. Five miles farther up the river is Kittanning, the type locality for the middle of the Allegheny section. The upper part of the following section is by I. C.

White, U. S. Geological Survey Bulletin 65, page 109. This includes down to the Lower Kittanning coal. The section below the Lower Kittanning coal is mainly from the quarry of the Kittanning Clay Manufacturing Company, taken by Charles Butts, U. S. Geological Survey Bulletin 279, page 163:

SECTION OF ROCKS AT KITTANNING.

	Feet.	Inches.
1. Coal; Upper Freeport,	4	
2. Shale and hidden,	35	
3. Coal; Lower Freeport,	2	
4. Hidden, and massive sandstone,	35	
5. Shale and sandstone,	40	
6. Coal, shaly in middle; Middle Kittanning,	1	6
7. Clay,	4	
8. Sandy shale,	6	
9. Clay,	3	
10. Sandstone, flaggy,	17	
11. Shale, dark, sandy, with iron ore,	40	
12. Coal; Lower Kittanning,	3	3
13. Clay,	12	
14. Shale, sandy,	10	
15. Iron ore,	1	
16. Limestone, Vanport,	9	
17. Shale, dark, sandy, or shaly sandstone,	10	
18. Shale,	20	
19. Coal; streak,		
20. Clay,	8-10	

The distance from the Upper Freeport to the Lower Freeport has decreased again to 35 feet, which is not far from the normal over the State. The Upper Kittanning is absent or is not seen in the section. The general correspondence of the Upper Freeport, Lower Freeport, Middle Kittanning and Lower Kittanning of this section and in the Logansport section seems very close. At once new difficulty arises. Not only is the so-called Upper Kittanning of the previous sections absent at Kittanning, but there is also absent another coal, which, under the name Darlington, has long passed in the western counties of the State as the Middle Kittanning, but which a large number of sections from the Allegheny front to the Ohio state line indicate belongs at or in the top of the shale above the Lower Kittanning coal. The Lower Kittanning has on very good evidence been considered to occur at practically the same horizon all through Pennsylvania. Over it there occurs with great persistence in county after county, a dark blue shale with iron nodules, so frequently as to suggest a bed of as widespread occurrence as the coal which it overlies. In the top of this shale is frequently found a coal. It reaches a workable thickness in Blair county on the east, and it is believed from the sections given in the bulletin on the Beaver quadrangle and those prepared for the Newcastle quadrangle that generally the coal designated as the Darlington coal at Darlington and in the western counties, comes at this horizon. This coal ranges from 20 feet to 40 feet above the Lower Kittanning, seldom up to 50 feet. Further, in a great many places over this shale is found a sandstone which lies upon it unconformably, and in many places can be seen descending sharply through the shale almost or quite to the Lower Kittanning coal. It may be rash to assert that this sandstone at different places is the same, and I will not so assert. At the same time, the evidence is suggestive. Again, at many places above this sandstone is a coal that would seem to correspond with the Middle Kittanning of the Kittanning section. This coal appears to be locally present above the Darlington in Beaver county. This is illustrated by a section by I. C. White on Paved Run, a tributary to Blockhouse Run, which enters Beaver river near its mouth:

SECTION ON PAVED RUN. I. C. W. SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA, REPORT Q, p. 194.

	Feet.	Inches.
1. Sandstone, massive,	30	
2. Coal, "Local" (Middle Kittanning at Kittanning),		5
3. Sandstone,	15	
4. Coal; Darlington,	1	6
5. Shale containing iron ore,	25	
6. Coal; Lower Kittanning,	2	
7. Clay,	6	
8. Sandstone, shaly,	54	
9. Limestone; Vanport, with shale partings,	8	6
10. Shale, dark,	15	
11. Hidden to Beaver River,	65	

In a case of this kind it can not be asserted that this 5-inch coal is continuous with the Middle Kittanning coal at Kittanning, or even that it occurs at exactly the same horizon and was laid down at the same time. The most that can be done is to suggest the latter premise as a working hypothesis, to be proven or disproven if possible.

In Beaver county the distance from the Upper Freeport to the first coal below is somewhat abnormal as compared with the interval farther east, as it runs commonly from 60 to 70 feet, and the distance from this coal to the Lower Kittanning is correspondingly shortened, averaging usually about 120 feet, as against 146 feet at the type locality, and an average of about 160 feet for the central counties in general.

By continuing up the Allegheny and Clarion rivers into Clarion county the lower part of the section may be obtained, and the section typically completed. Unfortunately there does not appear to be any definite type locality for the Clarion coal group. Probably no part of the Allegheny formation is less known than the Clarion coal group, especially below the Vanport limestone. Ordinarily the section between the Lower Kittanning coal and the Vanport limestone will show about as follows:

AVERAGE SECTION FROM LOWER KITTANNING COAL TO THE VANPORT LIMESTONE, CLARION COUNTY. G. H. A.

	Feet.	Inches.
Coal; Lower Kittanning,	3	
Clay,	8	
Shale, dark, with iron nodules,	5	
Clay, olive, with iron nodules,	10	
Iron ore, 3 inches-	1	
Limestone; Vanport,	6	

North of Sligo two new elements enter; a bed of flint clay and a coal bed. In general when the flint clay is present the limestone is absent, and it was at first thought that the clay might be in some way the result of the decay of the limestone. It, however, belongs distinctly above in the section. Just at the first cross-roads south of Sligo the following section appears:

SECTION JUST SOUTH OF SLIGO. G. H. A.

	Feet.	Inches.
1. Coal; Lower Kittanning,	3	
2. Clay, 20 inches to	2	
3. Coal,		3
4. Flint clay,		4
5. Clay, brown,	4	
6. Sandstone, gnarly, gannister,	2	
7. Clay, dark-brown and black,	5	
8. Sandstone, brown,	2	
9. Sandstone, shaly,	3	
10. Limestone, Vanport,	2+	

North of Sligo the two coals are seen in nearly every road section, the upper bed usually maintaining its normal thickness for the region of 3 feet, the lower bed ranging from 9 inches, but in many regions thickening up to as many as 27 or 33 inches. The space between them ranges from 4 to 10 feet in most sections, made up of clay where small, and of clay and shale where large. Where the lower bench becomes 2 feet or more thick in some cases the upper

Southwest of Shippenville, near Elkhorn schoolhouse, is one of the most interesting sections of the rocks and coals of the Clarion coal group.

SECTION SOUTHWEST OF SHIPPENVILLE. G. H. A.

	Feet.	Inches.
1. Coal; lower bench of Lower Kittanning; bloom.		
2. Interval,	5	
3. Flint clay; outcrop.		
4. Interval,	30	
5. Coal, bloom,		9+
6. Sandstone, shaly,	30	
7. Coal,	1	8+
8. Shale and sandstone,	40+	
9. Coal,		3
10. Shale, pink, and clay,	6	
11. Shale, purple,	14	
12. Coal,		4
13. Sandy shale at top. Sandstone, brown, at bottom,	6	
14. Coal,		5
15. Clay,		5
16. Sandstone,		6
17. Clay,		5
18. Coal,		8
19. Clay into shale,	3	
20. Sandstone, thin-bedded, cross-bedded,	15	
21. Coal, top bony,	1	6
22. Sandstone or shale,	46	
23. Sandstone, brown, medium-grained to coarse-grained,	42	
24. Shale, black,		6
25. Clay, sandy,	1	
26. Coal,		3
27. Clay, drab, and shale,	6	
28. Shale, sandy, drab,	6	

The presence of sandstones near the bottom of this section suggest that the two lower coals may belong in the Pottsville, in which case the Homewood sandstone is represented by a thickness of only 15 feet. In case only the lower coal is in the Pottsville, the coal No. 21 would represent the Brookville, and the other coals Nos. 5, 7, 9, 12, 14 and 18, may represent a split-up condition of the Clarion or they may represent local coals at different horizons.

Other sections might be cited to indicate either that the Clarion coal tends to split, as was supposed by Mr. Chance, or that coals were laid down at a number of overlying or overlapping horizons, or that both theories are true. In the Clarion region there seem to be very generally at least two Clarion coals and often more.

Most of the sections of Beaver county show only two coals between the Upper Freeport and the Lower Kittanning. The section on the east bank of Beaver river opposite Beaver Falls by I. C. White will give a good general idea of the sections in that region:

SECTION OPPOSITE BEAVER FALLS. I. C. W., SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA, REPORT Q, p. 201.

	Feet	Inches.
1. Sandstone, very massive; Mahoning,	40	
2. Shale,	1-2	
3. Coal; Upper Freeport,	3-4	
4. Clay,	2	6
5. Limestone; Upper Freeport,	3	
6. Shale, sandy,	35	
7. Sandstone, massive; Butler,	30	
8. Coal; "Lower Freeport,"	1	4
9. Clay and hidden,	3	
10. Shale, sandy, and sandstone "Freeport,"	75	
11. Coal; Darlington,	1	8
12. Shale, sandy, with iron ore,	35	
13. Coal; Lower Kittanning,	2	5
14. Clay,	12	
15. Sandstone and shale,	70	
16. Limestone; Vanport, 6 inches to	1	
17. Shale, Dark, calcareous, fossiliferous,	5	
18. Sandstone and shale,	20	
19. Coal, shaly; Clarion,	1	
20. Shale, sandy,	40	
21. Hidden to river,	30	

This simple type of section is preserved in the Allegheny formation to the south, as well as to the west of the type localities on Allegheny river, as is illustrated by a section on Cucumber run, Stewart township, Fayette county, as reported by M. R. Campbell:

SECTION ON CUCUMBER RUN, FAYETTE COUNTY. M. R. CAMPBELL, FOLIO 82, p. 8.

	Feet.
Mahoning sandstone.	
Shale—0-10 feet.	
1. Coal, Upper Freeport,	3
2. Clay,	3
3. Limestone; Freeport,	5
4. Concealed,	4
5. Shale, green, and clay,	5
6. Shale, sandy,	19
7. Fire clay; Bolivar,	6
8. Mudstones, green,	5
9. Concealed,	8

	Feet.
10. Coal; (Lower Freeport).	
11. Fire clay,	2
12. Sandstone, green,	10
13. Shale, sandy,	10
14. Concealed (sandy shale),	15
15. Coal; Kittanning upper,	4-7
16. Fire clay,	3
17. Sandstone, coarse,	18
18. Concealed (sandy shale),	35
19. Sandstone, shaly,	15
20. Coal,	2
21. Fire clay,	3
22. Shale, sandy,	20
23. Coal (thin),	
24. Concealed (shale),	60
25. Brookville-Clarion coal,	2¼
26. Shale or clay,	10
Pottsville sandstone.	
Total,	267¼-270¼

In partial contrast with the Beaver Falls section may be given a detailed hand-leveled section measured by Mr. Phalen and the writer just south of Kernville, at Johnstown, in Cambria county. This section was washed clean in the bed of a wash descending the hill at an angle of 40 degrees or higher:

SECTION SOUTH OF KERNVILLE, CAMBRIA COUNTY. G. H. A.

	Inches.	Feet	Inches.
Clay, sandy, light-drab and light-brown,		18	
Shale at top with nodules, to shaly sandstone at bottom,		12	
Sandstone, gray, massive; Lower Mahoning,		30	
Shale, dark,		1	
Coal,			2
Shale, dark drab, black at bottom,			2½
Coal; Upper Freeport:			
Coal,	44		
Clay, light-drab,	4		
Coal,	3		
		3	3
Clay, light-drab and dark-drab,		2	6
Coal,			3
Clay, soft, light-brown,		5	
Shale, drab, sandy, to shaly sandstone,		22	
Sandstone; hard, brown,		14	
Shale, drab, sandy,		3	
Sandstone,			2
Shale, black carbonaceous,			4

			Feet	Inches.
Coal; Lower Freeport:				
	Feet.	Inches.		
Coal,	1	2		
Shale,		1-2		
Coal,	2			
Shale,		½		
Coal,		4		
			3	8
Limestone, impure,			2	6
Clay, drab,				9
Limestone,				9
Clay to shale, drab, sandy, with many iron nodules,			6	
Clay, light-brown,				2
Clay or shale, drab, sandy,			9	
Sandstone, gray, shaly,			5	
Shale, drab, sandy,			7	
Coal; Upper Kittanning,			3	9
Clay to shale, sandy,			1	3
Limestone; Johnstown cement bed, shaly,			5	
Clay, drab, sandy, with much iron,			2	
Sandstone, shaly, gray to light-drab,			8	
Shale, hackly fracture, iron lenses, sandy,			27	
Coal; Middle Kittanning,				11
Clay, light-drab,			2	
Clay, light-drab, sandy,			4	
Shale, dark-drab, sandy,			14	
Shale, drab,			6	

Here the Upper Freeport, Lower Freeport and Upper Kittanning are beautifully displayed, all three coals coming within a space of 84 feet. Limestones under the Lower Freeport and Upper Kittanning coals are well displayed. The limestone under the Upper Kittanning coal has long been known as the Johnstown cement bed. The Lower Kittanning coal is estimated at from 30 to 50 feet below the bottom of this section. The 11 inches of coal may correspond to the Middle Kittanning of the type locality. This section of the Allegheny may be completed by another one measured at Scalp Level in northern Somerset county. The top of this section would appear to about join onto the bottom of the preceding section:

SECTION AT SCALP LOCK, NORTHERN SOMERSET COUNTY. G. H. A.

	Feet	Inches.
Sandstone, gray, shaly,	8+	
Coal; Darlington, 10 inches to	1	
Clay, drab,	5	
Shale, dark-drab, fissile, with plates of sandstone,	20	
Coal,		6
Sandstone, dark-drab; shale at top,	2	
Coal; Lower Kittanning; only top showing at railroad level,	1+	

		Feet	Inches.
Hidden,		16	
Sandstone, stained red,		1	
Shale, black, fissile,		2	
Clay; light-drab, sandy,		4	
Sandstone, greenish-gray, shaly; shale locally, stained red,		20	
Hidden,		5	
Sandstone, shaly,		4	
Shale, drab, sandy,		17	
Coal; Brookville:			
	Inches.		
Coal,	10		
Shale,	4		
Bone,	6		
Coal,	6+		
		2	2+
Hidden,		10	
Sandstone, Pottsville,		6+	

Turning to the northward and tracing the general sections across Clarion and Jefferson counties to Clearfield county, there is noted a marked tendency toward an apparent increase in the number of coals, especially in the Kittanning group. A couple of sections from Clearfield county will express these conditions there. The first is in the main exposed beside the road running north from Graham station west of Philipsburg. It is supplemented by sections from the Guion and Reakirt mines adjoining:

SECTION AT GRAHAM STATION, CLEARFIELD COUNTY. G. H. A.

			Feet	Inches.
Shale,			4	
Coal; Lower Freeport (Moshannon, "D,")				
	Feet.	Inches.		
Coal,	3	6		
Clay,		2		
Coal,	1	3		
			4	11
Clay,			2	
Shale, sandy, and shaly sandstone,			15	
Shale, black, about,			1	
Shale, light-drab,			18	
Coal; Upper Kittanning "C:"				
	Feet.	Inches.		
Coal,	1	3+		
Shale, drab,		7		
Coal,		11		
			2	9+
Clay, drab,			1+	
Sandstone, shaly, and shale, light-drab, sandy,			24	
Coal (Gorman),			1	4+

			Feet	Inches.
Shale, sandy,			5	
Sandstone, shaly,			8	
Shale, drab,			20	
Coal; Middle Kittanning "C:"				
	Feet.	Inches.		
Coal,		6-7		
Bone and shale,		1-2		
Coal,	3	7		
			4	4
Hidden; shale,			24	
Coal in air shaft (Darlington),			1	6
Shale, drab,			16	
Coal; Lower Kittanning, "B,"			2	10
Clay,			5	
Sandstone,			2	
Shale,			10	
Sandstone,				
Coal; Clarion or Brookville, "A,"				
		Inches.		
Coal,		6-0		
Clay,		30		
Coal,		15		
Bone,		1-2		
Coal,		26-28		
Clay,		2-3		
Coal,		3-4		
			7	4

A second section has been made by combining air shaft sections at Houtzdale with the section of a shaft to the "B" coal and drillings below the "B" coal:

SECTION OF ALLEGHENY FORMATION AT HOUTZDALE.

	Feet	Inches.
Coal; Upper Freeport "cap seam,"	3	
Shale,	20	
Sandstone and shale,	5	
Shale,	2	
Sandstone,	1	
Shale,		9
Sandstone,		6
Shale,	4	
Coal,		10
Shale, black,	2	6
Sandstone,		6
Shale, black,	1	
Coal; Lower Freeport (Moshannon "D,")	5	
Clay,	1+	
Interval to top shaft,	13	8
Surface material,	14	5

			Feet	Inches.
Sandstone,			1	
Shale,			32	2
Coal,			1	2
Shale,			4	6
Coal and shale,			1	3
Shale,			16	5
Sandstone,			38	
Shale,			1	2
Coal,			3	
Clay,			1	5
Shale,			14	5
Coal,				5
Clay,				5
Shale,			14	
Coal,				8
Shale,			18	5
Coal; Lower Kittanning "B:"				
	Feet.	Inches.		
Coal,	2			
Shale,		8		
Coal,	1	5		
			4	1
Bottom of shaft.				
Shale,			1	6
Sandstone,			4	4
Clay,			2	
Sandstone conglomerate,			4	
Coal,				3
Clay,			4	
Sandstone,			14	3
Shale,			18	6
Coal; "3-foot:"				
	Feet.	Inches.		
Coal,		8		
Shale,		2½		
Coal,	2	1½		
			3	
Shale,			1	
Shale,			10	9
Clay shale,			12	8
Sandstone,			7	8
Shale,			2	
Shale and clay,			2	
Shale with coaly streaks,				5
Sandy shale,				5
Coal and shale partings,			6	11
Sandy shale,			1	
Sandstone, Pottsville,			3+	

Other sections add still additional coals to the number in the Kittanning group. A drilling from those made in the Curwensville quadrangle may be given to show the same tendency to an increase in the number of Allegheny coals in that district:

DIAMOND CORE DRILLING IN WESTERN CLEARFIELD COUNTY.

	Feet.	Inches.
Coal; Upper Freeport, "E,"	2	4
Clay shale,	8	4
Sandstone,	3	3
Clay shale,	4	6
Sandstone,	5	7
Clay shale,	26	5
Coal; Lower Freeport "D" (Moshannon),	2	10
Clay,	1	7
Shale and clay,	8	
Sandstone,	15	1½
Clay shale,	7	
Sandstone,	4	9½
Clay shale,	1	
Bony,		6
Coal,	1	7½
Clay shale,	20	2½
Bony,		1
Coal,		4
Sandy shale,	15	9
Coal,		2½
Sandstone,	2	6½
Clay shale,	2	¾
Sandy shale,	24	6½
Clay,	2	¾
Sandy shale,	10	
Sandy shale,	7	2¾
Coal, bone and sulphur,		8¼
Clay shale,		2
Coal and bone,		1¾
Clay shale,	6	8¾
Sandy shale,	20	3
Sandstone,	7	6
Sandy shale,	16	5
Bony and shale,		8¾
Coal, bone, and coal,	1	7
Clay shale,	8	6
Sandy shale,	4	11½
Bony,		8¼
Sandy shale,	10	10
Coal,		1½
Clay shale,	13	3½
Sandstone,	4	
Sandy shale,	8	6¾
Coal and bony,		2
Coal,	1	2
Sandy shale,	24	
Coal,	1	1½

	Feet.	Inches.
Sandy shale,	2	3½
Bony,		2¼
Coal,		2

The general stratigraphy of the Allegheny formation has been gone into in more detail than the preceding formations, partly because it occupies a much broader field and in that field shows greater variation, and partly because development has not been as close, and therefore it has not been so well known as the Upper Productive Measures, and more attention has been necessarily given to the study of this formation in the field than was needed in the Pittsburg field. In the third place, the irregularity of these measures has necessitated a large amount of core drilling for prospecting purposes that has thrown a flood of light on the stratigraphy of this part of the section.

CHARACTERISTIC MEMBERS.

Upper Freeport Coal. The Upper Freeport coal is one of the most persistent and valuable coals of the Allegheny formation. In some areas it appears to be entirely absent, while in others it is injured or partly removed by contemporaneous erosion. It is the "Lemon bed" of eastern Cambria county, and probably the Kelly coal of the Broadtop field. It is usually broken up with partings, sometimes so as to be unworkable. At other places it becomes shaly. It appears to have originally been laid down over all or nearly all of the area within its outside limits, but the uplift and erosion which followed soon after its deposition removed or ruined large areas of it.

Upper Freeport Limestone. This limestone is very commonly found underlying the Upper Freeport coal at a distance of from 0 to 40 feet. It is usually from 1 to 5 or 8 feet thick, though running up to 30 feet as a maximum. It is usually ferruginous, often brecciated in appearance, and usually of a light-gray color weathering buffish.

Bolivar Fire Clay. Associated with the Upper Freeport limestone and lying a short distance below, is often found a high grade fire clay. It has long been mined at Bolivar, Westmoreland county, and it is noted in nearly or quite all of the counties in which the Upper Freeport coal outcrops. Fragments of the clay are frequently found in the roads below the outcrop of the Upper Freeport coal. It has been little prospected, though worked at a number of points. It is reported from points in Ohio and West Virginia, where it is occasionally valuable.

Upper Freeport Sandstone (Butler Sandstone). Twenty-five to 60 feet of space between the Upper and Lower Freeport coals is often filled with shale, though some sandstone is found there, and often a massive bed of sandstone appears between the two coals. This bed of sandstone has been called the Upper Freeport, or Butler sandstone.

Lower Freeport Coal. Present information suggests that instead of coal at a single horizon, there may be several closely overlying or overlapping coal horizons in the space from 30 to 65 feet below the Upper Freeport coal. This coal has always been recognized as a variable one, sometimes reaching a thickness locally of 15 or 16 feet, though nearby being entirely absent. In other regions, as in the Moshannon Basin in Clearfield county, this bed is known to split. In Cambria county it is known to be represented by coals at nearly the same, but slightly overlapping horizons. In Jefferson county the laying down of its roof shales was followed by an erosion period that removed large areas of the coal, and made careful prospecting necessary before development, so that on the whole, while this bed has yielded some of the finest bodies of coal yet found in the areas underlain by the Allegheny formation, as the Moshannon, the Punxsutawney, Reynoldsville Basin, and around Barnesboro, plans to work this coal should be preceded by careful prospecting.

Lower Freeport Limestone. This limestone resembles that under the Upper Freeport coal, except that it does not appear to be quite so persistent or so thick. Both were apparently laid down in fresh water.

Lower Freeport Sandstone (Freeport Sandstone). While resembling the Upper Freeport sandstone in many ways, this sandstone is apt to be more persistent, thicker, and often coarser grained. In places it becomes a true conglomerate. Frequently this sandstone appears to unite with the sandstone below the Upper Kittanning coal so as to form a sandstone mass 75 to 80 feet thick.

Upper Kittanning Coal (Cement Coal). In general this is a coal bed of very minor importance. It possibly gains in importance in the south part of the State. It is a workable bed 6 feet thick south of Johnstown, and is the thickest bed in the Allegheny formation along Chestnut Ridge in Fayette county. At the north it is frequently characterized by the presence of cannel coal, which locally will increase its thickness to from 12 to 20 feet. Nearly or quite all of the cannel coal of the State appears to be at this horizon. It has been so found in Clearfield, Indiana, Armstrong, Clarion and Beaver counties. In some of the counties the cannel coal at this horizon, while having all of the appearance of cannel in grain, cleavage, luster, et cetera, shows on analysis a composition similar to ordinary bituminous coal. At Cannelton, Beaver county, it is a true cannel coal, and has long been mined and used for the manufacture of oil.

Johnstown Cement Limestone. At Johnstown the Upper Kittanning coal is underlain by a limestone that like the Upper and Lower Freeport limestone is suitable for the manufacture of natural cement. This limestone is less frequently found than the two preceding limestones, and appears to have been laid down over a much smaller area.

Middle Kittanning Coals. The plural is here used to express the group of coals occurring between the Upper and Lower Kittanning coals. Whether these occur at persistent and definite horizons can not yet be stated. In Clearfield county there appear to be at least three or more of these coals, and it has been suggested that the variable vertical position of coals in this space may be due to the occurrence of non-persistent coals at several distinct and persistent horizons. As a rule, in Pennsylvania coals in this part of the group are of little commercial value, but they occasionally become so, and in Ohio the famous "Great Vein" of Hocking Valley and elsewhere, has been corelated with the Middle Kittanning of Pennsylvania. Elsewhere it is suggested that the names Gorman, Middle Kittanning and Darlington, as each is applied at its type locality, may truly name three horizons at which non-persistent coals are often found.

Lower Kittanning Coal. This bed of coal is believed to be probably the most persistent stratum of the Lower Coal Measures, and though not so readily recognizable as the three great key rocks, it actually probably underlies an area as large as that underlain by all three key rocks put together, and this notwithstanding that it is an extremely irregular bed in some parts of the State, apparently being made up in those places of several benches that come and go, or separate and unite. In places it is known to have split. In other places it is thought to have done so, yet notwithstanding there is almost persistently found a coal bed in this position, underlain usually by a clay bed of unusual thickness and value, often by a fire clay bed which locally is of value, and over a large area by the characteristic and widespread Vanport limestone. Though variable in some areas, there are other large areas, as in Johnstown and Ebensburg quadrangles, where the bed as a whole is very persistent, even though some of the associated benches run in and out. In Clarion county again it is very persistent, varying only between narrow limits, and the same is true in Beaver and Lawrence counties and probably in the intermediate counties.

Considering it broadly this bed very seldom has a thickness of less than 20 inches, and very seldom has more than 4 or 5 feet of coal, though with the partings it often runs up to 6 feet or over in thickness. The writer has traced it miles at a stretch where it would hardly vary 3 inches either way from an average. It varies in purity, in southern Cambria county being very pure, while in eastern Clearfield it is usually sulphury and high in ash.

A broad study of the sections of this coal suggest that most of the seeming irregularity is not due to changes in the main bench, but to the presence or absence of one or more benches below the main bench. This is fairly well brought out in fig 9, and a comparison of that with the sections of this coal reported by Mr. Phalen in the Johnstown quadrangle (U. S. Geol. Survey Bull. 316, p. 32 and following) strengthens that view for there 8 inches will cover the variation of the main bench in any of the districts, while below this main bench are one or two benches that vary with every measurement from 0 to 36 inches, and the same is true elsewhere.

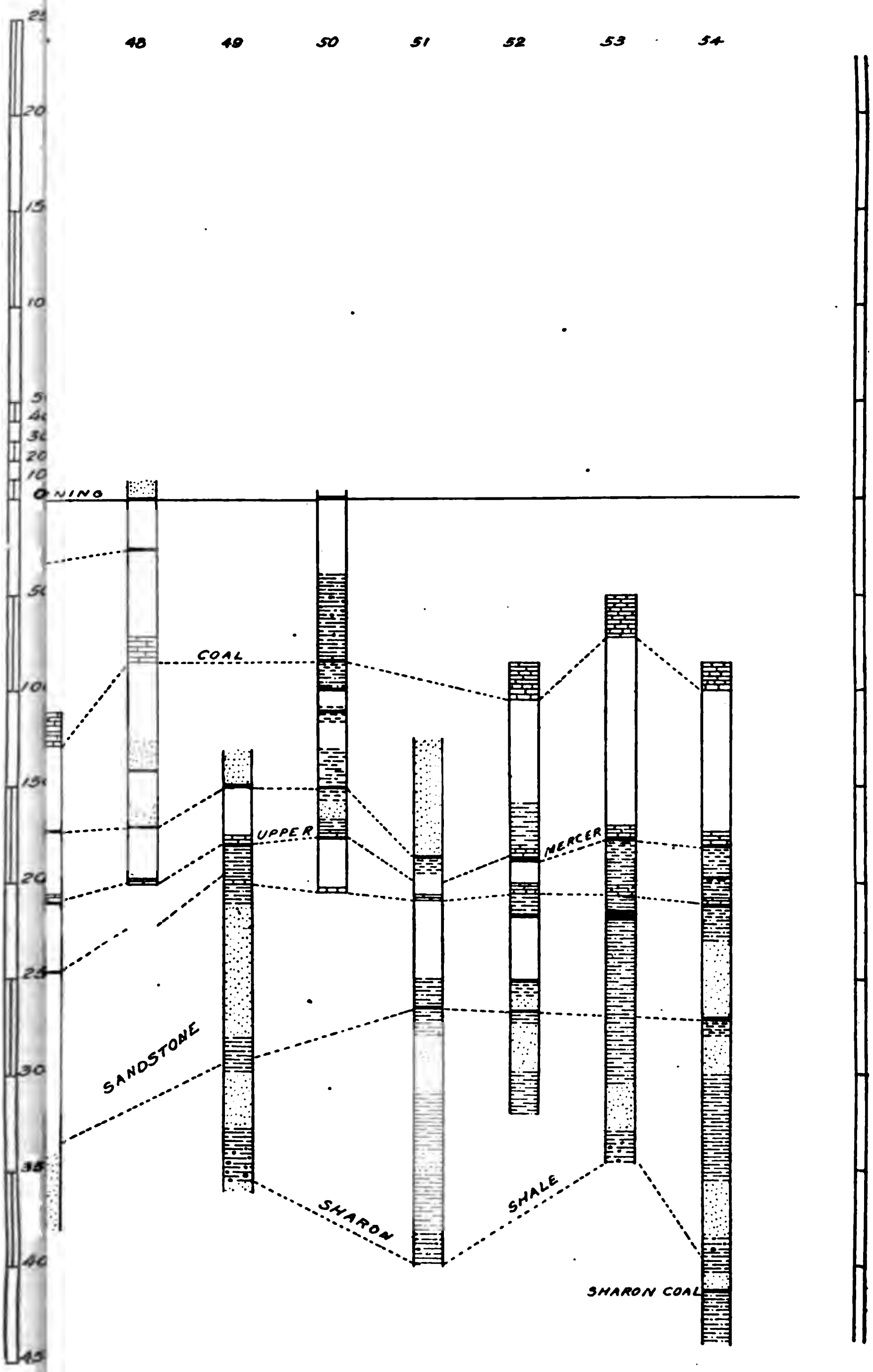
Lower Kittanning Clay. Just under the Lower Kittanning coal is what is possibly the most important clay horizon in Pennsylvania. The clay is usually of the soft variety, often 10 to 12 feet thick, and has been extensively utilized in Beaver county and in probably every other county in Pennsylvania, where it outcrops, as well as down the Ohio river in Ohio, and even down into northeastern Kentucky. In many districts there tends to be associated with this clay 6 feet or less of flint clay. This is most widely distributed in Clarion county, where it outcrops in the streets of the town of Clarion. Flint clay at this horizon has been found at least in Clarion, Jefferson, Indiana, Clearfield and other counties, and as far south as northwestern Kentucky, where a thin bed only a few inches thick, of black flint clay, persistently occurs with the soft clay. Flint clay at this bed has been extensively mined near Clearfield, and to a less extent in Clarion county and elsewhere.

Vanport Limestone and Iron Ore. While not as widespread or persistent as the Lower Kittanning coal and its associated clay, this limestone has much more value as a key rock where it is found. It differs from the higher limestones of the Allegheny formation in Pennsylvania by the presence of an abundant marine fauna with certain typical forms, and in the frequent presence of a layer of iron ore over it. A study of the relation of the iron ore and limestone by Mr. Phalen led him to conclude that the iron deposit resulted from the concentration of the iron from the highly ferruginous upper part of the limestone, due to the partial solution of the limestone and its removal. This bed is from a few inches to one foot thick, though occasionally found thicker where under favorable circumstances the whole limestone bed has been dissolved and removed, leaving the iron. The iron appears to be confined to the surface within reach of surface percolating waters. When followed in, the ore tends to become more calcareous, finally passing into ferruginous limestone. Iron nodules in which the limestone core still exists, and much similar data, testify to the correctness of this view.

The limestone is often thin or entirely absent, and appears to be confined to the district west of Chestnut Ridge anticline. When thin or impure, it often shows "cone in cone" structure. The relation of this bed of limestone to the Putnam hill limestone of Ohio has been a subject of some question in the past. A study of Andrews' sections in southern Ohio has led the writer to believe that future study will show beyond question that the "Blue" or Putnam hill limestone of Ohio is the Upper Mercer limestone of Pennsylvania. Recent work by David White in northwestern Kentucky has shown that the distance from the Lower Kittanning coal to the top of the Homewood sandstone has decreased in southern Ohio until it is often only 10 to 15 feet, the Lower Kittanning coal, the Vanport limestone, and the Brookville or Clarion coal in that district lying almost in contact. Below this is the massive Homewood sandstone, and below that a coal and limestone with plants of Mercer age. By plotting up Andrews' sections, it is readily seen that the same succession holds northward to Putnam Hill, and that the so-called Clarion sandstone of these sections is of Pottsville age.

Clarion Coals. The subject of the Clarion coals has been gone into at some length in preceding paragraphs, and need only be touched on here. As the Clarion and Brookville coals have been little sought by the drill, our knowledge of them has mainly been derived from outcrops, too often along gentle hill slopes involving dips and other elements that tend to render the sections taken at these points uncertain and unsatisfactory. While often only one coal is found between the Lower Kittanning and Brookville coals, there is evidence for thinking that this single coal when so found may be at quite different horizons in different regions, whereas in many places the evidence is abundant that there are at least two or three coals in this space. While sometimes workable, none of these coals is of any widespread value.

Brookville Coal. This coal is the lowest member of the Allegheny formation. It is an important coal around Brookville, and in eastern Clarion county. An important coal at about this position is found in the southern part of the State, and is a very important coal in West Virginia. Its exact correspondence with the Brookville coal has not been established. As with the Clarion coals, the Brookville has been little sought with the drill, and but little mined in, so that its stratigraphy and character are not well known. In general, it does not appear to be an important coal in Pennsylvania.



P tsville in its type region.

31 first ravine north of Morado; 37, at Homewood; 38, bluff north of Homewood
(B south of Chewton; 43, south of Wampum; 44, hill southwest of Wampum;
45, upper part; 51, Covert; 52-54, off the north edge of the quadrangle.

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POTTSVILLE FORMATION.

General Character. In the area covered by recent co-operative work, the Pottsville has played a small part. In many of the quadrangles it is not exposed at all, and in most of the quadrangles the exposure is very limited, often to where one of the stronger anticlines is cut by the larger streams. Further, within the area studied it contains little or no workable coals, so that it has attracted little attention. The formation in Pennsylvania, however, is a valuable source of building stone, and is the source of some of the highest grade fire clay in the State.

In most of the area of the map accompanying this report it consists of three members: the Homewood sandstone at the top, the Mercer coal group, and the Connoquenessing sandstone. To the northeast in the Newcastle quadrangle the Connoquenessing sandstone is double the two benches separated by the Quakertown coal, and below these are the Sharon coal and sandstone. Apparently the central part of Pennsylvania was above water during the laying down of coal and sandstone at the northwest. The studies of David White have shown further that the Sharon, as well as the later deposits, represent only the later part of·Pottsville time, as represented by the deposits of Pottsville in the anthracite field or in the southern Appalachian coal field. In West Virginia and eastern Kentucky the Pottsville has a thickness of 5,000 feet or more, and the strata equivalent to the Sharon, Connoquennessing, Mercer and Homewood of Pennsylvania are on the Kanawha river over 1,000 feet thick. Within the area here studied the best sections are to be obtained on the Beaver river in the New Castle quadrangle. These are well represented in the sections on Plate VII, obtained by Mr. DeWolf. As shown by those sections, the formation there consists of a massive sandstone at the top 20 to 65 feet thick, a group of two or sometimes three coals, two or which are commonly overlain by limestone and are known as the Upper and Lower Mercer coals, an irregular though often massive sandstone, the Upper Connoquennessing, one or two thin coals, the Quakertown, a massive lower Connoquennessing sandstone, the Sharon coal and shale, and below that the massive Sharon sandstone not shown in these sections.

Homewood Sandstone. This sandstone has its type locality in the New Castle quadrangle at Homewood. The sandstone there consists of 65 feet of massive sandstone, as exposed in the main upper quarry. This is underlain by from 15 feet to 0 of shale, both on the west side of the gorge in the old quarry and on the east side below the church on the road. This shale contains typical Mercer plants. At the big upper quarry this shale is partly cut out, and the Homewood sandstone appears as though united to the Upper Connoquenessing sandstone which is here 90 feet thick and forms the lower quarry. It was at one time thought that all of this sandstone represented the Homewood as usually developed elsewhere, that the upper part projected up into the space of the Allegheny formation, and that the lower part of the Allegheny was deposited against or around this projecting knob. The work of Mr. DeWolf and David White has shown that the Allegheny members are all in place above the top of the sandstone, and that more than the lower half is of Connoquenessing age. Recent studies have deprived the Homewood sandstone of no small part of its formerly supposed importance; nevertheless it probably remains to-day as one of the most prominent and persistent sandstones of the Pennsylvania series. It is extensively quarried in Beaver and Lawrence counties on the west and in Clearfield and other counties on the east.

Mercer Coal Group (including the Mt. Savage clay). This group derives its main value from the presence in it of the Mercer or Mt. Savage fire clay. In many places this is a flint clay of the highest grade. The distribution of this clay will be discussed under the head of clay. This group contains two or three coals in Beaver river. It contains two coals in western Clearfield county, but over most of the area here studied it contains only one coal. The coals are usually thin and worthless, though occasionally they reach a workable thickness.

Connoquenessing Sandstones and Quakertown Coal. Over most of the area these sandstones and this coal are practically unknown factors in the stratigraphy. Where exposed on hill slopes they are usually entirely covered by the debris from the massive overlying Homewood, and so can not be observed, and they have been hardly at all penetrated by drilling. They are perhaps better exposed on Beaver river and along Connoquenessing creek than elsewhere in the region studied. As shown by the sections, the sandstones do not as a rule fill more than a part of the space from the Mercer to the Sharon, and in some cases the sandstone is a very inconspicuous part of the section.

The Quakertown coal often occurs in an interval filled with shale 50 to 60 feet thick. This often contains more than one coal bed, the coals usually being only a few inches thick and worthless.

Sharon Coal and Sandstone. Though at one time one of the most valuable coal assets of Ohio and northwestern Pennsylvania, the Sharon coal is now nearly worked out. It barely appears at the northern edge of the New Castle quadrangle. Where well developed the coal is found to have been deposited in irregular lagoons or channels having a thickness in the center of several feet of very high grade household coal, but thinning rapidly on the edges of the lagoons or channels. Traced through Ohio the Sharon sandstone is nearly everywhere a prominent sandstone forming the base of the coal measures. Passing into Kentucky it is thought that this sandstone expands and becomes one of the great sandstones of the Pottsville, as developed on the Allegheny front and Cumberland mountains of that region.

PRE-PENNSYLVANIAN STRATIGRAPHY.

BY CHAS. BUTTS.

General Statement. Under this head are described the geologic formations beneath the unconformity between the Pennsylvanian rocks above and the Mississippian rocks below, the rocks above the unconformity having been described in the preceding section of this report. The rocks included in this discussion extend down to the top of the Trenton limestone. For the most part, these strata are not exposed within the limits of the bituminous coal basin of western Pennsylvania. The upper formations outcrop along the northwest margin through Mercer, Venango and Warren counties, and still lower formations further north and northwest in New York and Ohio. All the formations down to the Trenton outcrop immediately east of the Allegheny Front in Bedford, Blair, Centre and Clinton counties. As shown by the sections (Plate IX), they lie deep below the surface of the coal field. Deep well borings have yielded a fair knowledge of these rocks down to a horizon that appears to lie near the bottom of the Hamilton formation. The character and thickness of the formations below that horizon can only be assumed from the character and thickness exhibited at their outcrop. Since this discussion begins with rocks immediately below the above-mentioned unconformity, a description of that unconformity will first be given.

THE MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY IN WESTERN PENNSYLVANIA.

General Statement. The existence of an unconformity between the Mississippian and Pennsylvanian rocks in western Pennsylvania has been clearly established by the work of the U. S. Geological Survey during the past eight years. This unconformity was recognized by I. C. White,* but its details were not worked out. The existence of the same unconformity in the Southern Appalachians has long been recognized by workers in that field.

In western Pennsylvania the rocks immediately concerned in this discussion are roughly, as follows:

	Feet.
Pottsville:	
Connoquenessing sandstone,	100
Sharon shale,	50
Olean (Sharon) conglomerate,	40

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*Bull. 65, U. S. Geological Survey.

	Feet.
Pocono-Waverly:	
Mauch Chunk formation,	50 to 2,000
Burgoon (Logan, "Big Injun,") sandstone,	400
Shale, limestone and sandstone (Cuyahoga),	500
Berea (Corry) sandstone,	50
Catskill-Erie shale (in part):	
Knapp formation,	100
Conewango formation, with Salamanca conglomerate lentil (Cattaraugus and Oswayo formations of Glenn, Rept. New York State Paleontologist, 1902),	500

Work done on the Latrobe and Kittanning quadrangles in 1901 showed that the Mauch Chunk thins westward and disappears from the section in Allegheny Valley. The Olean conglomerate and Sharon shale are also absent, and the Connoquenessing sandstone rests upon the Burgoon sandstone. In 1904 Geo. H. Girty completed studies in northeastern Ohio and northwestern Pennsylvania which enabled him to identify the Berea sandstone of Ohio with the Corry sandstone of Pennsylvania, and to trace the latter definitely by its very characteristic assemblage of fossils to the Allegheny river at Warren, where it, in places, lies close below the Olean conglomerate, the latter bed in places lying on beds below the Berea on account of the erosional unconformity in the region. This determination of Mr. Girty explained the difficulty experienced by the writer in 1900, in referring to their proper stratigraphic position the beds immediately below the Olean conglomerate in the Olean New York region.*

It was supposed at that time, from the stratigraphic relations of these beds, that they were the equivalent of the Waverly rocks of northeastern Ohio since both lie immediately below the Olean conglomerate. The rocks below the Olean in New York and western Pennsylvania which were named the Knapp, Oswayo and Cattaraugus beds by Glenn (loc cit.), and are here called Knapp and Conewango formations, carry an entirely distinct assemblage of fossils from the Waverly rocks of Ohio, and the writer was unable to correlate them with any previously described rocks. Girty's work shows that they are to be correlated with the upper part of the Erie shale of Ohio, which carry some of the highly characteristic fossils of the Conewango rocks, though that fact has not, to the writer's knowledge, been published. The section from the Allegheny Front, in Blair county, to Allegheny river at Kittanning, had thus been worked out, and that from northern Ohio to the river at Warren. It only remained to connect the two sections by the river section between those two places to have a complete line of section from central Pennsylvania to northern Ohio. In the fall of 1907 the writer made a continuous section along Allegheny river from the New York Pennsylvania boundary to Emlenton, where the rock section is substantially identical with that just above Mahoning on the Kittanning quadrangle.

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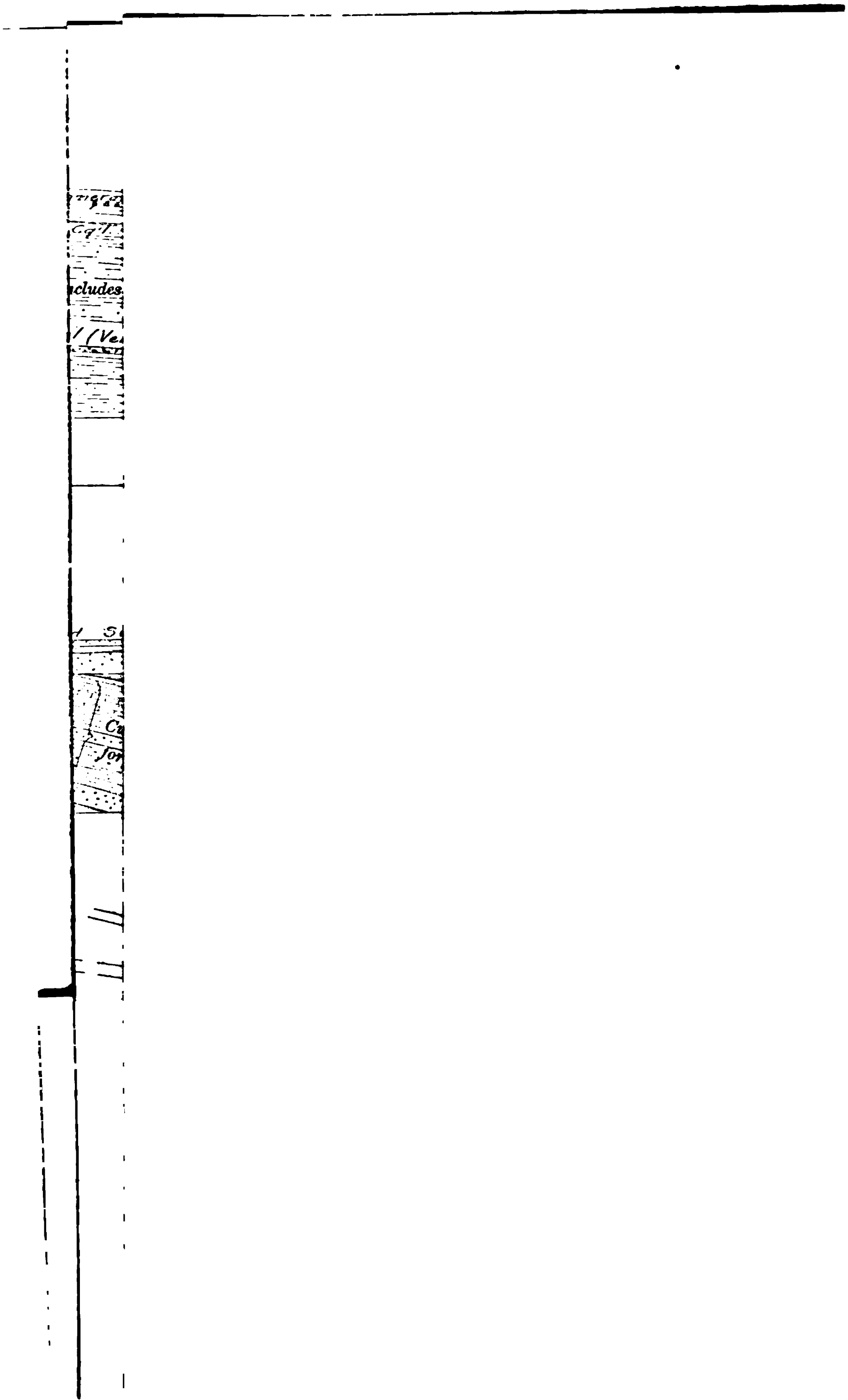
*Rept. New York State Paleontologist, 1902.

Description of Allegheny River Section. This section appears as Plate VIII. The base of the section is the Pennsylvania Railroad, which lies about 20 feet above the river the whole distance, no allowance being made for the decrease in altitude between the State line and Emlenton, which is about 340 feet. Excepting the part of the section between Oleapolis and Oil City, all outcrops from railroad level up to about 100 feet were platted to scale in making the field notes, and every few miles sections were made on the bluffs up to the Pottsville beds that generally cap them. The continuous profile section (Plate VIII) is constructed from the observations just described, and is believed to represent closely what would be seen if the valley walls were vertical and the strata were continuously exposed. However, in connecting detached observations, allowance must always be made for errors in the identification of beds though certain prominent and fairly well exposed beds served to connect up the sections at different points, so that there is little doubt as to the correctness of the section as a whole. Thus, the Salamanca conglomerate can be traced from Corydon, near the State Line, to the point where it passes below the railroad level 2 miles or so below Tidioute. The Berea sandstone, lying 300 feet above the Salamanca, can be identified by its characteristic fossils in every section down to the bend of the river 2 miles south of Tionesta, where it in turn passes below the railroad grade. About 160 feet above the Berea, and separated from it mainly by blue shale, is a rather thin-bedded, generally fine-grained, sandstone. This was traced with a good degree of certainty from 2 miles south of Tidioute to a point about 1 mile south of Hunter, from which point it is exposed at many places near railroad level and was traced continuously to Oleapolis. A similar, and probably the same, sandstone is exposed at Oil City at railroad level and dips below the railroad about 1½ miles south of Oil City. At Henry's Bend the Shenango sandstone is exposed as a ledge about 230 feet above the railroad, and it can be traced with certainty south nearly to Wood Hill.

The Shenango Sandstone is regarded as the basal part of the Burgoon ("Big Injun") sandstone of Pennsylvania, and as the equivalent, in part at least, of the Black Hand formation of Ohio, the Burgoon as a whole being regarded as the equivalent of the Black Hand and Logan formations.



Castle prevails. In No. 7, in the northern part of the Warren quad-

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It appears from the section that from Oil City to Emlenton the Burgoon and Connoquenessing lie nearly parallel to each other without any discordance of bedding, so that the only means of discriminating them, especially in the Kittanning region, where they are lithologically very similar, is their fossils. They preserve the parallel relations and practically the same thickness as far north as Hunter, where a monoclinal flexure, much exaggerated in the figure on account of the exaggerated vertical scale, carries the beveled edges of the Burgoon beds up against the bottom of the Connoquenessing sandstone, with the total disappearance of the Burgoon, including the Shenango sandstone from the section farther north. Apparently, another such upward bend of the strata below the unconformity in the vicinity of Cobham and Thompson stations led to the erosion of most of the Cuyahoga beds before the deposition of the Olean conglomerate, which is the basal member of the Pottsville north of Tidioute. It may be remarked, in passing, that no trace of the Olean was seen in the bluffs south of a point 2 miles south of Tidioute. At Tionesta the Pottsville was not seen in place, but boulders of white, siliceous sandstone, regarded as Conoquenessing, lie on the top of the bluff west of the town. The Olean has been represented, therefore, as thinning out entirely between Tidioute and Tionesta.

Section South of Kittanning. The many deep wells from the Kittanning region to the southwest corner of the State show that the Connoquenessing and Burgoon sandstones are in contact to the vicinity of Pittsburg, where the Mauch Chunk red shale, with the Greenbrier limestone, appears in the section between them. This increases in thickness to about 200 feet in the southwest corner of the State. These facts are shown in Plate IX.

General Summary. The facts concerning this unconformity in the State are conveniently summarized and graphically expressed by the sections in figure 18.

In section No. 1, in the anthracite field, the Mauch Chunk is 2,200 and the Pottsville 1,200 feet thick, with apparently no unconformity, or only a slight one, between them. In No. 2, on the Allegheny Front, all but the top, 130 feet of the Pottsville and 180 feet of the Mauch Chunk are absent. In No. 3, at Latrobe, the situation is the same, but the Mauch Chunk is only about 50 feet thick. In No. 4, at Kittanning, all the Mauch Chunk is wanting, and the Conoquenessing sandstone rests upon the Burgoon sandstone. In No. 5, at New Castle, the Burgoon is wanting, and the Olean conglomerate rests upon the Cuyahoga shales. In No. 6, in the southern part of the Warren quadrangle, nearly the same condition as at New Castle prevails. In No. 7, in the northern part of the Warren quadrangle, all the Cuyahoga is absent, and the Olean is in contact with beds below the Cuyahoga formation. In No. 8, in northeastern Ohio, the Cuyahoga is present and 250 feet thick beneath the Pottsville.

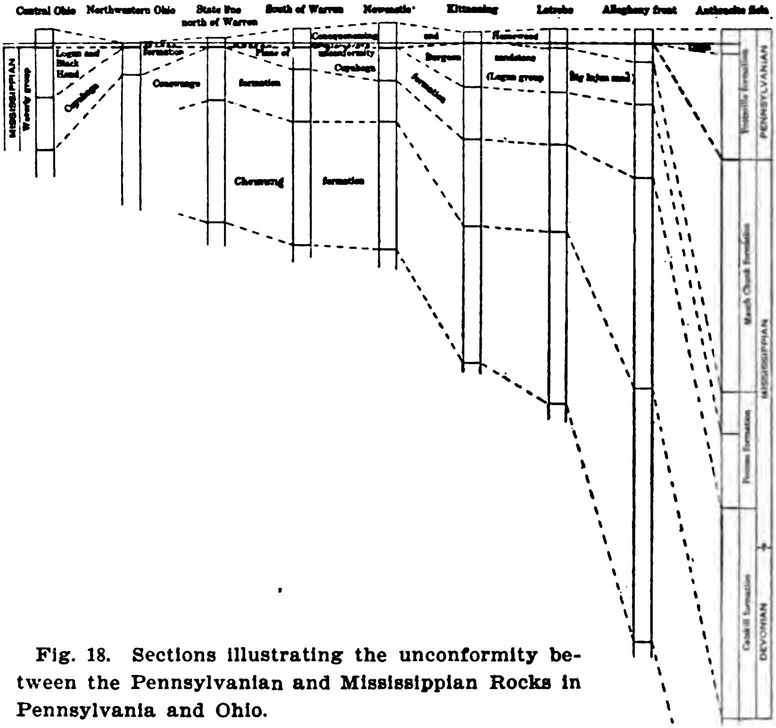
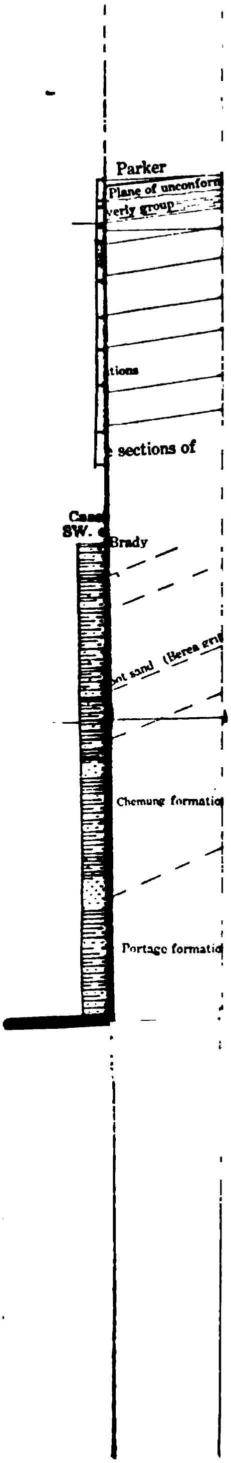


Fig. 18. Sections illustrating the unconformity between the Pennsylvanian and Mississippian Rocks in Pennsylvania and Ohio.

In central Ohio the full Waverly group including the Logan and Black Hand conglomerates, which are the equivalent of the Burgoon sandstone and the Cuyahoga shale are present below the Pottsville.

The history of events leading to the conditions described above is somewhat as follows:

Sedimentation was continuous over western Pennsylvania and eastern Ohio, with the deposition over that region of the Pocono-Waverly beds, probably in their full thickness of 1,000 feet or more, and it may be, a considerable thickness of Mauch Chunk, though it is hardly probable that the latter formation reached the thickness of 2,200 feet as in the anthracite field. At the close of Mauch Chunk time the region outlined above was broadly uplifted, the axis of the uplift appearing to be somewhere in the neighborhood of a line extending from New Castle to the western corner of New York State. The uplift was also greater northward. During early and middle Pottsville time, while the most of the Pottsville formation with its included coal beds, was being deposited in eastern Pennsylvania, the uplifted area was a land surface subject to erosion,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with the result that the Mississippian beds, once probably present, but now absent from western Pennsylvania, were removed. After this period of erosion a gradual subsidence began and the land was transgressed by the waters in which the late Pottsville sediments were laid down. The submergence apparently proceeded from the northwest. Since the Olean conglomerate, the lowest member of the Pottsville in the region lies to the north and west of a line roughly drawn from Wellsboro, in Tioga county, through Smethport, in Potter county, Sheffield and Tidioute, in Warren county, to Mercer and New Castle, in Mercer and Lawrence counties, respectively, the most advanced shore line of the Olean waters apparently lay near the line just outlined. After the deposition of the coarse gravel making the Olean conglomerate, the land mass was entirely submerged and the Connoquenessing sandstone was deposited over the whole region, thus completing the cycle of uplift, erosion, submergence, and the resumption of deposition over the region affected by the unconformity.

Correlation of Oil Sands. The unconformity above described has an important bearing on the subject of the identification and correlation of the oil sands of western Pennsylvania. In the original Venango county oil field three sands were encountered and named the Venango 1st, 2d and 3d sands, as shown in the section of the Hain's well, Plate IX. As operations extended to other parts of Pennsylvania these names were also applied to the sands which were believed to be the same beds as at Oil City and Titusville. Thus, at Tidioute Carll[*] regarded as the 1st Venango sand, and White[†] as the 2d Venango sand what proves on tracing northward to be the Salamanca conglomerate. The last identification was also made by those authors. According to the writer's section, Plate VIII, however, the Salamanca is the same as the Venango 3d, and the Berea sandstone the same as the Venango 1st sand. Carll[‡] identifies the Venango 1st sand with the Butler 2d sand, otherwise generally known as the 100-foot sand. Carll also published a plate of oil well sections[§] showing the continuation of the Venango sands from Oil City and Franklin to Clarion, and the Clarion section has been recently connected by Munn (unpublished) with the Kittanning Rural Valley region studied by Butts,[||] with the result that the 100-foot sand of Butler and Armstrong counties has been satisfactorily identified with the Venango 1st sand, thus confirming Carll's earlier conclusion referred to above. The 100-foot sand is regarded with good reason as the equivalent of the Gantz and

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[*] I 4, Economy oil well section pp. 31-48.
[†] Q 4, p. 71.
[‡] I 3, p. 272.
[§] I 3, pl. 6.
[||] Kittanning and Rural Valley Folios and Bull., U. S. Geological Survey, No. 279.

50-foot sands of Washington and other southwest Pennsylvania counties, though the Butler-Armstrong counties region has not been closely tied up by continuous lines of carefully-studied well sections with the southwestern counties. There still remains a gap of some miles to be studied. A comparison of the geologic section in Butler and Armstrong counties with that of Washington county, however, makes it appear probable that the identification of the 100-foot with the Gantz and 50-foot sands is correct. To sum up, then, the Berea sandstone is the same as the Venango 1st sand, the 100-foot sand and the Gantz and 50-foot sands. This affords a good reference horizon for the comparison of the oil sands throughout the western part of the State. It appears, furthermore, that the sand called Berea, in Beaver county and in southeastern Ohio, probably is not the Berea, but the equivalent of the Murrysville sand, which lies 100 feet or so above the 100-foot, or Berea sand.

CARBONIFEROUS SYSTEM—(Continued).

Mauch Chunk Formation. In the central and southwestern part of the State, the Mauch Chunk formation lies immediately below the unconformity just described. Along the Pennsylvania Railroad on the Allegheny Front, west of Altoona, this is 180 feet thick, composed of 80 feet of thick-bedded, fine-grained, greenish, sandstone at bottom and 100 feet of red and green shale at top. Where exposed on the Chestnut anticline in Fayette county it is 150 to 200 feet thick, composed of red and green shales, with the Greenbrier limestone lentil 20 to 30 feet included, near the bottom. As noted above the Mauch Chunk can be identified in well logs as far west as Saltsburg and is 50 to 100 feet thick on the Conemaugh river; and also from the southwest corner of the State where it ranges from 100 to 200 feet thick until it thins and disappears from the section a few miles south of Pittsburg. Wells a few miles south of Punxsutawney show no Mauch Chunk, and the western margin of that formation lies farther east. A line representing approximately the north and west edge of the Mauch Chunk would run west from a few miles south of Pittsburg to the Ohio-Pennsylvania State line, and from the same locality northeast through Saltsburg and Indiana, probably crossing the southeastern corner of Jefferson county. North and west of such a line the Pottsville is in contact with the Pocono formation, save for here and there possibly an outlying patch of Mauch Chunk.

Pocono Formation (Waverly Group). Along the Pennsylvania Railroad, on the Allegheny Front, the Pocono is 1,100 feet thick, having 400 feet of sandstone at top and 700 feet of shale and sandstone at bottom, this part containing a number of beds of red shale like the red shale of the underlying Catskill. The upper sandstone member is the Burgoon sandstone. On the Chestnut anticline on Youghiogheny river, the lower shaly part of the Pocono appears to be wanting, the Burgoon sandstone resting upon beds carrying a fauna that suggests the Conewango formation of the northwest part of the State described beyond (p. 198). This subject is reverted to on p. 198. The Burgoon sandstone is one of the persistent beds throughout western Pennsylvania and southeastern Ohio, being present in every deep well throughout most of the region and known to the driller as the "Big Injun" sand. Its position with respect to overlying formations which form the surface is shown on the plate of profile and well sections (Pl. IX). West of the Allegheny Front the Burgoon comes to the surface only along Allegheny Valley, of which it forms part of the walls from Mahoning, a few miles north of Kittanning, to Tionesta, where it is beveled off by erosion and disappears from the section, the overlying Pottsville coming into contact with the shale below it. It loses much of its heavy sandstone character and becomes more or less shaly northward. It appears from the studies of DeWolf (unpublished) that the Burgoon also disappears from the section between Allegheny river and New Castle. A line therefore roughly indicating its northwest edge might be drawn from Beaver Falls in a curving direction passing north of Franklin and Oil City to Tionesta, and eastward to connect with the line described on p. 196, to indicate the northwest edge of the Mauch Chunk, the Connoquenessing sandstone being in contact with some part of the Burgoon over the included area.

It appears from a comparison of a complete section of the Ohio Waverly Group with the Pocono section of western Pennsylvania that the Burgoon is the equivalent of the Logan and Black Hand conglomerates (Logan Group of Orton), and that the shale and sandstone below the Burgoon are the equivalent of the Cuyahoga shale and Berea sandstone, the latter being the basal member of the Pocono. Actual tracing by means of well borings from western Pennsylvania to central Ohio also practically establishes the equivalence of the "Logan Group" with the "Big Injun" sand.* The shales below the Burgoon likewise rise to view along the river above Emlenton and can be traced without mistake into the Cuyahoga shale of the Ohio, so that the practical equivalence of the Pocono and Waverly seems well established.

Unconformity at the Base of the Burgoon. In 1878 Stevenson* published a list of fossils collected in Conemaugh and Youghiogheny Gaps through Chestnut Ridge. The fossils were collected in the 150 feet immediately underlying the Burgoon sandstone, some of

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*Orton, Gol. Ohio, Vol. VII, P. 34.
†American Journal of Science, 3d Series, Vol. 15, 1878, pp. 423-430.

them within 18 inches of the bottom of that stratum. These fossils were pronounced Chemung by James Hall, to whom they were submitted for identification. On the strength of these fossils, Stevenson regarded the rocks containing them as Chemung. While a part of the forms occur in the Chemung, they also occur in the overlying Conewango beds to be described below, and in the writer's opinion the rocks in question should be referred to the Conewango, which is the equivalent of the upper part of the Catskill formation. This opinion is supported also by the fact that near Conemaugh Gap and to the west of Chestnut Ridge a body of red rock 150 to 400 feet thick is penetrated in deep wells drilled for oil and gas at a lower stratigraphic level than the beds bearing the fossils, a fact that indicates that they are above the bottom of the Catskill. Furthermore, Stevenson reports red layers in the rocks exposed in the gaps mentioned above just as they occur in the Conewango formation.

From the above, it follows that apparently the Cuyahoga formation and Berea sandstone are wanting across the crest of the Chestnut anticline, it either having been eroded from that area or never deposited there. During Cuyahoga time there possibly existed a reef or low barrier along the line of the Chestnut anticline which received no sediment but which sank at the close of the epoch so that the sediment composing the Burgoon (Pocono "Big Injun") sandstone were deposited upon it in their full thickness.

It is to be noted that the Conemuagh and Youghiogheny gaps lie at a distance from the Allegheny Front, where the Catskill is typically developed that is comparable to that in the northern part of the State where the Conewango fauna exists in beds regarded as the equivalent of the upper part of the Catskill. This subject will be discussed under the next head.

Conewango and Catskill Formations. As in the case of the Waverly and Pocono, the "Conewango and Catskill" formations are, in part, at least, contemporaneous, though differing much in lithologic and paleontologic character. On the Allegheny Front the Catskill formation is 2,000 feet thick and mostly red shale and sandstone carrying in localities abundant fish remains, but no marine invertebrates. The formation dips west beneath the bituminous coal basin and does not reappear with the same character as it has where it disappears beneath the overlying rocks. It can be traced nearly continuously around the north end of the basin through Clinton, Cameron, Potter, McKean and Warren counties. In the distance from Lock Haven, Clinton county, to Warren, Warren county, the formation changes gradually from red to green, and the fossil fish are replaced by a fairly abundant marine invertebrate fauna, while in the same distance the thickness changes from 2,000 at Lock Haven to 500 or 600 feet at Warren. In the Warren region, only two or three thin red bands occur. The red bands are nearly, or quite, nonfossiliferous, the fossils occurring only in the green and gray beds. This feature is still more striking in the Olean New York region and in eastern McKean county, where the red bands are thicker and there is a greater number of them. To this western aspect of the Catskill rocks the name Conewango formation has been applied by Butts in the Warren Folio, and the names Cattaraugus and Oswayo beds in the Olean region.* The Conewango is 500 to 600 feet thick. Since the Conewango and Catskill merge into each other laterally it will be impossible to find a sharp line of division between them, and where the name Conewango shall cease to be applied and the name Catskill begins will have to be decided on the ground of expediency. It appears from the stratigraphic studies so far made that the Conewango rocks represent the upper part of the Catskill where that is typically developed, and the fossils indicate strongly that the rocks should probably be regarded as carboniferous, though that is still a debatable question. Dr. Geo. H. Girty has been studying the subject for a number of years and has a report in progress of preparation in which he will describe the fauna and discuss its bearing on the question of the age of the Conewango.

The presence of red layers and strata from a few to 400 feet thick is shown by thousands of deep well logs throughout almost the entire bituminous basin from the Allegheny Front to Ohio and New York, and it is plain that there is across the whole width of the State from New York to Maryland the same transition from red beds on the east to prevailingly gray beds with thin red layers on the west that there is across the northern counties, as described above. Furthermore, the same thinning westward prevails and the Conewango beds are only 200 to 300 feet thick along the west line of the State. This thinning is shown on the profile section, plate IX.

The Conewango includes most of the Venango oil sand group, but it does not include the Berea sandstone, which is the first or 100-foot sand, that bed being included in the Pocono. Scattering red layers, probably to be included in this phase of sedimentation, also occur below the bottom of the Venango sands, and these are thicker and occur at lower horizons eastward.

It appears as though the main body of red sediment was derived from the east and deposited east of a line 15 to 20 miles west of the Allegheny Front, and that west of that line only at times of large supply or under especially favorable conditions of transportation were the red sediments transported westward, occasionally to the western confines of the State, and laid down as a red band in the midst of prevailingly green gray sediment, probably derived from the northwest, thus forming an alternation or interfingering of the two kinds of sediment. To the west the conditions appear to have been marine, as attested by the presence of marine fossils, but eastward the conditions were different, either the water or sediment being inimical to marine life, except possibly that of fishes that could move easily from place to place as conditions changed. It is commonly believed that the fishes the remains of which occur in the typical Catskill formation were of fresh water habitat.

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*Glenn Rept. New York State Paleontologist, 1902.

DEVONIAN SYSTEM.

The Devonian is a great shale and sandstone system with a limestone included at the base. It is divided into the following formations: Chemung, Portage, Genesee, Hamilton, Marcellus, Oriskany and Helderburg.

Chemung Formation. The Chemung is composed predominatingly of thin, fine-grained, argillaceous sandstone, and shale, commonly called by the oil-well driller, slate and shells. On the Allegheny Front it is 2,400 feet thick, in southwestern New York and northwestern Pennsylvania it is about 1,100 feet thick, and it is assumed to have about that thickness throughout the most of the central bituminous basin. In northwestern Pennsylvania its upper limit is here placed at the top of the "pink rock" described beyond, and its lower at the top of the Bradford oil sand of McKean county, or at that horizon as nearly as it can be determined where the sand is absent or thin. The upper part of the Chemung, both on the Allegheny Front and in northwestern Pennsylvania, is marked by a large proportion of purplish shale and sandstone. In the former region the purplish rocks extend through the upper 1,000 feet, and in the latter, through the upper 300 feet or so. In Warren county the purplish beds are called "pink rock" by oil-well drillers. It is possible that the red rock noted at a considerable depth below the probable bottom of the Venango sands, in here and there a deep well in the southern and central part of the Bituminous basin is really this "pink rock" and is to be included in the Chemung. The Chemung is very fossiliferous. Its fauna is sharply differentiated from the overlying Conewango and ceases at the top of the "pink rock," only a very small proportion of the species extending upward into the Conewango, while none of the characteristic species of the Conewango occur in the Chemung. The oil sands of Warren county, and the Spechley and Tiona sands in the central part of the basin lie near the middle; and the Bayard and Elizabeth sands of southwestern Pennsylvania lie near the top of the formation.

Portage Formation. The Portage formation outcrops in western Pennsylvania only along the shore of Lake Erie. It also outcrops east of the Allegheny Front, its bottom lying within the limits of Altoona. In the Altoona section the Portage is 1,600 feet thick. It is not known in the Bituminous basin except from well borings. Throughout the oil fields it is regarded as comprising the 1,000 feet or so of gray, sandy shale and thin sandstone intervening between the Chemung formation and the soft, dark shale of the Hamilton formation. It would be classed in the driller's category of "slate and shells." It is penetrated in whole or in part by all the deep well sections of Pl. IX, except the Caseman well in southwestern Greene county, where it lies below the bottom of the well. In McKean county the Bradford oil sand is probably the same as the sandstone making the top of the Portage formation at Portageville, N. Y. Outside of the Bradford oil field the Bradford sand can not be identified with certainty, but in some of the wells that have penetrated deep enough a thin sand has been noted lying near its probable horizon, and the top of the Portage has been drawn at that position.

At its nearest outcrop east of the Allegheny Front the Portage is composed mostly of stiff, greenish, sandy shale, with thin interbedded greenish sandstones. Included at the base is 100 feet or so of very thinly and evenly laminated pale gray or dove-colored shale. The formation is very sparingly fossiliferous, the fossils being almost wholly minute pelecypods. Along the line of well sections (Pl. IX) the rocks identified as Portage are about 1,000 feet thick, as shown in the Starbrick, Conway and Bedell well sections.

In central Pennsylvania the Portage was not discrimintaed from the Chemung in the reports of the Second Geological Survey of Pennsylvania, but the separation has been made in the Ebensburg Folio, and to that publication the reader is referred for a discussion of the grounds upon which the separation was made.

Genesee Shale. The Genesee shale outcrops from beneath the Portage formation along the east of the Allegheny Front. It is black and probably averages 75 feet thick. It can not be satisfactorliy identified in the well sections of the oil regions and may be assumed to have disappeared from the section or to have so changed as to be unrecognizable under the conditions.

Hamilton and Marcellus Formations. At Altoona the Hamilton and Marcellus formations are apparently 2,000 to 3,000 feet thick. The Hamilton is dark greenish, hackly shale above and darker fissile shale below, containing bands of sandstone. The Marcellus is a black fissile shale probably not over 200 feet thick. In the Starbrick well section (Fig. 1, Pl. IX), underlying the greenish sandy shale referred to the Portage, are 1,000 feet of dark shales, with limestone and calcareous shale in the lower third, that are here regarded as Hamilton. In the Bedell well (fig. 5, Pl. IX) are 985 feet of dark shales with limestone bands throughout that are here referred to the Hamilton, though Dr. I. C. White expressed the opinion that the well stopped in the Marcellus. The Starbrick well stopped in a very black shale with calcite that seems almost certainly referable to the Marcellus. This shale was penetrated to a depth of only 10 feet. It appears reasonable, therefore, to assume that the Hamilton is about 1,000 feet thick throughout the axial part of the Bituminous basin. A complete suite of drillings from the Starbrick well shows that the Hamilton is a dark, to chocolate, soft clay shale which is highly calcareous for 200 feet or so above the base. In the midst of the calcareous stratum is a bed of limestone 32 feet thick. In the Conway well (Fig. 2, Pl. IX), and in a well at Titusville known as the Watson well a limestone was encountered at a great depth that is probably the same as the limestone in the Starbrick well. This limestone was regarded as the Onandaga (corniferous) by Carll,[*] but the presence of over 200 feet of dark shale below it in the Starbrick well shows that that identification is probably erroneous. The presence of thin limestone bands through the full thickness of the Hamilton in the Bedell well (Fig. 5, Pl. IX) shows the progressive increase in calcareous contents to the southwest.

Rocks Below the Hamilton Formation. As shown in the preceding discussion, our direct knowledge of the underground rocks of the Bituminous basin extends down only to the bottom of the Hamilton formation or thereabouts. The Starbrick well near Warren apparently reached the Marcellus, while the Bedell well at West Elizabeth may have reached the same horizon or may have stopped a little short of it.

The character and thickness of the deeper lying rocks are necessarily matters of speculation and inference based upon the rocks as they outcrop around the margins of the basin in Maryland, Pennsylvania, New York and Ohio, but especially in the first two mentioned States, where their outcrop is nearest to the center of the basin. A general section of these rocks down to the Trenton limestone averaged from measurements in Blair and Bedford counties, Pa., and near Cumberland, Md., made by the geologists of the Pennsylvania Second Survey and the Maryland Survey is as follows:

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[*] I.5, p. 72.

Oriskany sandstone,	177
Helderberg limestone,	353
Salina, Niagara, and Clinton shales and sandstones with limestone layers,	1,800
Medina sandstone,	425
Medina Shale,	1,060
Utica shale, etc.,	850
Total,	4,665
Top of Trenton limestone,	

On the Allegheny Front, in Blair and Bedford counties, Pennsylvania, and at Cumberland, Maryland, the average thickness of the rocks from the top of the Catskill to the Oriskany sandstone is 7,660 feet. At Warren, Pa., the known thickness of the equivalent rocks to the bottom of the Starbrick well is 4,160 feet and is probably 100 feet or so thicker since the drill did not go through the Maracellus. In the Bedell well at West Elizabeth the same beds are known to be 3,572 feet and are probaly thicker since here also the black shales, either Marcellus or Hamilton, were not passed through. If we add 200 feet it would make the thickness 3,772. These thicknesses in the middle of the Bituminous basin will be seen to be approximately one-half of the thickness of the same rocks in the Allegheny Front, and it may be fairly assumed that the deeper lying rocks thin to the same extent westward, so that a section at Pittsburg, for instance, would be as follows:

Oriskany sandstone,	88
Helderberg limestone,	176
Salina, Niagara, and Clinton shales and sandstones with limestones,	900
	1,164
Top of Medina sandstone,	
Medina sandstone,	212
Medina shale,	530
Hudson and Utica shales,	425
	1,167
	2,331
Top of Trenton limestone,	

Since all the above formations, with the exception of the Oriskany, and possibly the Salina, can be discriminated in Ohio, where they emerge from beneath the Bituminous basin, it is reasonably certain that they persist underneath that part of the basin included in Pennsylvania, so that the above section may be regarded as fairly reliable as to character, thickness and sequence of formations.

Assuming that the Bedell well at West Elizabeth stopped within 100 feet of the top of the Oriskany sandstone, it would have been necessary to drill 1,264 feet deeper, or, say, 1,300 feet, to reach the Medina sandstone and 2,467 feet deeper to reach the Trenton limestone. In other words, at West Elizabeth the Medina lies, according to the above calculations, at the depth of 6,875 or a little over 5,000 feet below sea level, while the Trenton limestone lies at the depth of 8,042 or a little over 7,100 feet below sea level. The depths given above may be considerably greater, but it is highly improbable that they are smaller, so it may be fairly assumed that, along the river in the vicinity of Pittsburg it would be necessary to drill, at the very least, to the depth of 6,875 feet to reach the Medina, and 8,042 feet to reach the Trenton. The position of these strata with reference to sea level under the Bituminous basin are sufficiently exhibited in the profile sections and need not be further discussed here. The depth at which they lie beneath the surface at any point will depend, of course, upon the location, upon the elevation of the surface, and upon the locality, the depth gradually diminishing to the northeast, as shown in section, Fig. 2, Pl. IX.

The practical bearing of this discussion lies in the fact that the Medina sandstone is an important gas producer in western New York, and the Trenton limestone is an important oil producer in Ohio, and the matter of drilling to those strata had probably suggested itself to many persons. In fact, the Starbrick well at Warren was drilled with the object of reaching the Medina, though the well was abandoned at something like 1,200 feet above that stratum.

The information given above should enable any one who may contemplate drilling to either the Medina or Trenton in the Pennsylvania oil and gas fields, to appreciate the magnitude of the undertaking and to suggest that the prospect of profit is too small to warrant the expense involved in such a venture.

STRUCTURE.

(See large folded map, Plate I).

General Statement. In the recent geologic work in which the Federal and State governments have co-operated the determination and delineation of structure has been considered as of the highest importance, and a large share of the work and its cost has been devoted to that side of the study. As work in this direction is a distinct advance over the work of the earlier surveys, and as men without engineering training are not familiar with the meaning of the word as here used, or the method of representing the structure in recent publications, the subject is here treated at some length and from a very elementary standpoint. There are four phases of the subject to be explained: (1) The meaning of the word "structure" as here used; (2) the method of its graphic representation; (3) the methods of its determination in the field; and (4) the degree of accuracy and reliability of the structure as presented.

If it were possible to remove all of the rocks lying above the top of any selected rock layer in western Pennsylvania, such as the Pittsburg coal, or, better, the top of the Upper Freeport coal, it would be found that the top of the layer formed a surface like that of a gently rolling country consisting, in the main, of low, rounded ridges or swells between equally gently rounded valleys. The ridges and valleys would be found in western Pennsylvania to have a general trend of northeast and southwest. Some of the ridges and valleys would be found to be very long, extending sometimes half way across the State, but in all cases the ridges would nose out and the valleys run out as two nearly parallel ridges run together and coalesce. This would be true only of the western part of the State west of a line which is followed by the east side of Cambria county. For a short distance west of this line the ridges and valleys would usually be quite long and narrow and regular. Further west they would usually be shorter, broader, and less regular, until along the western edge of the State this rock surface which we have assumed to have been exposed would appear to be a gently sloping surface, sometimes rising into oval or sugar-loaf mounds and similar depressions, but in general sloping toward a line drawn from Pittsburg southwestward toward Huntington, West Virginia. Further examination would show that this line was the axis of a major valley or basin, but that in going eastward from this line, the ridges and valleys occurred at higher and higher elevations. By structure here is meant the "lay" of any bed, or the shape of one of its bounding surfaces, as just described.

In the description of the history of this region given beyond, it is stated that in the main these ridges and valleys are folds produced by pressure from the southeast, as a bolt of cloth partly extended on a counter and pushed upon from one end will be thrown into many transverse folds or wrinkles. To the up folds or ridges the geologist gives the name "anticlines," to the down folds or valleys, the name of "synclines;" the direction of slope at any point is the "dip," and a horizontal line at right angles to the dip along the bed is the "strike."

Method of Graphic Representation. In attempting to represent the structure, three methods are used. One method is by hachure lines, or some modification of them; that is, on the map of the area involved, short lines are drawn in the direction of the dip. Usually the part of the line down the dip is made heavier than the opposite end. In this way it is possible to show the direction of the dip, the position of the anticlines and synclines, and, if the length of the line is varied as the dip varies, it may be possible to suggest whether the dip is high or low. In this method there is only one definite thing shown—the horizontal position of the axes of the anticlines and the synclines. All the rest is indefinite, and the method has, therefore, a very limited application from an engineering and practical standpoint. The second method consists in assuming that the rocks have been cut by a vertical plane and a drawing is made which represents the cut edges of the rocks where they are intersected by this plane. Such sections are shown in plate IX. Just along the line of its intersection this method represents the structure with entire definiteness and with as great accuracy as the facts observed or obtained will allow. It shows not only the horizontal position of the axes and folds at the points of intersection, but their vertical position as well, expressed, it may be, in feet above sea level, and the exact slope of the rocks between the various axes of the anticlines and synclines, so that the exact position, vertically and horizontally, of any rock being studied may be determined. This is the most vivid way of representing structure. It has this great disadvantage, however—it shows the structure only along the line of the section. If the anticlines and synclines are long and regular such sections a mile apart may give a very fair idea of the structure. If the structure be irregular the sections must be correspondingly more numerous and near together. It is evident at once that, while such sections may give accurate information of the structure along the lines of the sections and general information of the region in general, if it be desired to get exact information as to the dip of elevation of any coal or other rock bed or any point off from one of the lines of section, it can only be done with difficulty, and at best, approximately.

The third method is by the use of contour lines. This method, while not so readily understood, or so graphic in its portrayal of the folding as the preceding method, has the great advantage that it may be placed on a map with other features, and from the lines as drawn it is possible to determine at any point on the map the dip, strike and elevation of the rock surface that has been contoured. To understand the meaning of contours, let it be imagined, as before, that all of the rocks above the top or bottom of a selected layer be removed and that then the sea rises until just above the top of the highest fold, say, to an even number of 100 feet above its old level. Suppose now that it sinks 100 feet so that the top of the ridge projects slightly above its surface. If it remains at this level a short time it might be assumed to make a slight beach mark where the waters meet the ridge. Such a beach mark might consist of a slight wave cutting in the rock or only of an inconspicuous ridge of seaweed, sand, etc., such as is ordinarily thrown up at high water on any beach to-day Suppose the sea then sinks another 100 feet and remains until another beach mark has been made. Evidently the two beach marks will show the exact shape of the hill at the elevations above the old sea level at which the sea stood still. Where the slope from the first mark to the second was gentle the marks will be far apart. Where the slope was steep the marks will be near together. Assume then that the sea continued to sink, stopping at each even 100 feet long enough to make a beach mark, until it had returned to its old level; that a map of these beach marks had then been drawn and each marked with the elevations at which it was made. Such a line, when drawn on a map, is called a contour line. It is evidently a line of equal elevation, in this case, above sea level, and a map showing the structure by contour lines is called a structure contour map. The elevation of any point on one of the contour lines is, of course, shown by the designation of that contour line, but it is also evident that if the slope between any two adjacent contour lines be, or be assumed to be, even, the elevation of any intermediate point can at once be determined with close approximation. Thus, if a particular point on a map comes half way between 1,200 and 1,300-foot contours, its elevation may be assumed to be very close to 1,250 feet. If it be one-fourth the distance from the 1,200-foot to the 1,300-foot contour, its elevation is close to 1,225 feet, and so on.

So that if a map be made showing by 20-foot contours the structure of the surface at the bottom of the Pittsburg coal, an engineer, by turning to such map, can see at a glance the elevation above sea level of the Pittsburg coal to within 20 feet, and usually within 5 feet, either at the point at which he is standing or at any other point on the map about which he is interested, even though the coal at that point be hundreds of feet under ground. If, further, the map shows by contours the elevation of the surface of the land at that point, by subtracting the one from the other, he may obtain the depth below the surface of the bottom of the coal and will know at once how far he must drill or sink the shaft in order to reach the coal.

Methods of Determining Structure. In determining the structure, two general methods have been used. The first method is, briefly, to plot on the map all of the elevations of the selected surface it is possible to obtain, and then to connect them with lines of equal elevation. Thus, suppose that a map is being made in the Pittsburg coal field and the bottom of the Pittsburg coal has been selected as the surface to be contoured. If there be any mines on that coal in the area, copies of the elevation of the coal would be made from the mine maps of the companies. These would then be reduced by photography to the scale of the field map and the elevations transferred to the field map. Then there would be added to the map the elevations of the bottom of the coal at every point where it could be found in outcrop, as at small mines or "country banks," prospects or exposures in road, railroad or stream cuttings, or when seen as black smut marks across the roads. If any drilling has been done to prove the coal, or if there are oil or gas wells in the area which pierce the coal and the records of which give the depth of the coal, the elevations so obtained are added. When necessary, the elevations of the tops of the wells are determined in the field. Then having determined the elevation at the surface of other coals, limestones, sandstones or other rocks that outcrop, and knowing, or finding from a study of the stratigraphy, the distance from the Pittsburg coal up or down to the outcropping bed by adding or subtracting, as necessary, a great number of additional elevations on the coal may be obtained, until finally the field sheet of a single quadrangle may contain many hundreds of elevations on a single horizon. Then lines are drawn between points of equal elevation, the lines passing through or to one side or the other of any elevation as the elevation is just at, above, or below the elevation of the line being drawn.

In this case, the reliability and accuracy of the final result will depend upon two things: The abundance and uniform distribution of the elevations and the accuracy with which the individual elevations are determined. In the field the elevations are determined by the barometer, by the hand level or by the spirit level, or stadia. In all cases the measurements are checked on or measured from bench levels instrumentally determined in the making of the topographic map. Experience has shown that where frequently checked on bench marks, as in western Pennsylvania, barometric determinations will be correct within 50 feet, though the limit of error is hardly less than that. With the hand level the limit of error should not be more than 5 or 10 feet, while with the spirit level, or stadia, the limit of error should be well within 5 feet, and generally within 1 foot. The liability of being mistaken in the identification of the bed itself or of some other bed from which its elevation may be computed, is a constant possible source of error, as is also the constant possibility that the interval from an outcropping rock to the surface to be contoured may have changed from what it is at the nearest point at which this interval could be measured. This method, using in the main the spirit level, has been applied in the Burgettstown, Claysville, Carnegie, Sewickley and Clarion quadrangles.

In the second method, vertical cross sections are drawn to scale so as to make a complete network all over the quadrangle. Ideally, every square mile should be crossed by one or more of these cross sections. These cross sections are drawn so as to follow in a general way routes taken in the field study of the geology, such as the roads, railroads, streams, hill slopes, etc. In making the field study of the geology, the geologist draws in his note book a large scale profile of the ground as he passes over it, and on this he represents graphically and with abundant notes every particle of geological data he can obtain along the line he is traveling, not only actual exposures of the rocks, coals, mines, wells, etc., but everything about the soil or debris which may contain any clue to the character of the rock below. All of these data are placed on his profile at the proper elevation as determined by the barometer, hand level or spirit level. In the office the data are transferred from the field note book to the carefully drawn cross sections, the elevations being carefully corrected for any errors in the barometric readings where such can be detected. If the surface data are at all clear, it is usually then not difficult to draw what corresponds to the intersection of the plane with the horizon which it is desired to contour. The cross section paper used has horizontal lines, or they may be drawn to represent the vertical intervals at which the contours are to be drawn on the map. Where these horizontal lines cross the line representing the position of the bottom of the Pittsburg coal on the cross section, if that be the surface being contoured, or where the corresponding contour lines are going to cross the line of the cross section on the map, these points of intersection are drawn on the map and then connected together to form the contour map. In this method use is made of the levels from mine maps, drillings, etc., but all of the other data is taken into account as well. With a similar mode of obtaining elevations this method is much more accurate than the preceding. This is particularly true in the regions in which the outcropping rocks are mainly or entirely of Allegheny or Lower Conemaugh age, as in most of the Barnesboro, Patton, Punxsutawney, Curwensville and Houtzdale quadrangles, and large areas in some of the other quadrangles, where there is an entire lack of any rock that would serve as a key rock and where, in fact, the stratigraphic position of none of the coals, limestones, shales or sandstones can be determined by an examination of the rock stratum itself. Under these conditions, with the second method it is possible to carry the structure over large areas within which it is not possible to recognize the stratigraphic position of any outcropping rock.

If Figs. 6 and 7 be examined it will be evident that in a region in which such rocks are the outcropping rocks, and where almost none of the outcrops are in unweathered exposures, even the second method may yield only uncertain results. Over large areas in the quadrangles mentioned in the preceding paragraph just such conditions exist. Generally the presence of the sandstones has to be assumed from the scattering sandstone fragments on the surface. Often, where the land is all under cultivation the existence of stone fences or of small stone piles in the fence corners has been the best evidence obtainable of the presence and position of a sandstone. In certain places some sandstone has been locally more resistant than those above or below it, and its top can be traced around the hill slope by following the top of the scattered boulders that have been derived from it by weathering. The sections in Figs. 6 and 7 are fairly typical of the variations in the rocks of the Lower Conemaugh, and it will be noted that the distance from the top of what appears to be the same sandstone in adjacent sections down to the Upper Freeport coal varies so greatly that even though the top of such sandstone be traced for several miles it is not sure how closely the underlying surface to be contoured will follow the same levels.

Some of the difficulties of working out the structure are thus practically stated so that too much confidence may not be placed in the structure as shown. In general, the contour interval has been so chosen that the limit of error will not be greater than the contour interval. It is true that in many of the quadrangles over considerable areas the limit of error is well within the contour interval, but again, on the same quadrangles there may be areas in which the limit of error is much greater. In the latter cases it is usually planned to make the contour lines broken or dotted.

In contouring on an oil or gas sand, if the contouring is based mainly on surface data, it is usually necessary to take account of the fact that the distance from any one of the coal measure rocks down to the oil sands varies from point to point, due to the unconformity described by Mr. Butts. Thus, in going across the quadrangle, the distance from the Pittsburg coal down to the hundred-foot sand may increase several hundred feet or enough so that where the dip is low the corresponding features in the structure of the hundred-foot sand and the Pittsburg coal may not be vertically one over the other, but may be as much as a fraction of a mile apart. In preparing maps on the oil sands, allowance has been made for this factor by the construction of a "convergence" sheet. This is a drawing made on tracing cloth or paper, in which, in their proper position, are placed all the wells of which good records exist, and in which the distance from the contoured horizon at the surface down to the oil- or gas-bearing sand is given. This distance is noted at each of these wells on the map, and then lines of equal distance are drawn (called isochor lines) much as a contour map would be drawn. This is then placed over the structure map of the subsurface contoured horizon, and at each point at which a definite elevation on that surface is had an amount as shown by the isochor lines is subtracted to give the elevation of the oil-producing sand under that point. Having in that way obtained as many elevations on the oil sand as have been obtained on the key horizon, a structure contour map of the oil sand may then be constructed. This is explained and illustrated more fully in Bulletin 318.

The Structure as Represented. The most valuable part of this report is undoubtedly the accompanying map, on which is brought together, not only the distribution of the oil, gas and principal coals —in which respect it is but a revision of maps previously published—but for the first time the structure represented by contours is shown over a large part of southwestern Pennsylvania. Of the structure here shown, that of the New Castle, Sewickley, Punxsutawney, Carnegie, Curwensville, Houtzdale, Barnesboro, Patton and Johnstown quadrangles has not before been published. The structure on many of these sheets is provisional and subject to change before final publication. Probably never before has the detailed structure of so large an area been accurately represented, certainly not in this country. It therefore represents an opportunity for the study of the folding of the earth's surface under the conditions here existing that it is hoped may be taken advantage of in the future.

In drawing the structure of the large map, the Pittsburg coal was chosen as the horizon to be contoured rather than one of the lower and more widespread horizons, because a lower horizon would go below sea level in the southwest corner of the State—a condition that when represented is always apt to be misleading. In preparing the map the structure maps as published or prepared were photographically reduced to the scale of the new map and the structure transferred. In several of the quadrangles the structure as originally drawn on the maps was on the base of the Pittsburg bed. In these cases the structure was transferred without change. In other quadrangles various horizons have been used to contour on. The Washington limestone, Ames limestone, the Upper Freeport coal, the Middle Kittanning coal, the Lower Kittanning coal, have all been used. In these cases the distance was computed from the Pittsburg coal up or down to the layer actually contoured on in any case. Usually the figures were taken in round numbers, as 300 feet below the Pittsburg coal to the Ames limestone; 600 feet from the Pittsburg coal to the Upper Freeport coal, increasing to 750 feet at the east. To the Lower Freeport coal 50 feet additional were added, and to the Lower Kittanning 200 feet additional. By knowing the intervals from one coal to another in any of the quadrangles and the assumed interval from the Pittsburg bed to one of the coals in each quadrangle, the approximate elevation of any coal in the area may be computed from the map. Thus in the Punxsutawney quadrangle the interval from the Pittsburg coal to the Upper Freeport coal was assumed to be 700 feet. Therefore by subtracting 700 feet from the contours as drawn the actual elevation of the Upper Freeport coal at any point may be obtained. By subtracting 40 feet more, the elevation of the Lower Freeport can be obtained. Thus at Punxsutawney the Pittsburg coal is represented as theoretically 1,850 feet above sea level; 740 feet from that leaves 1,110 as the actual elevation of the Lower Freeport coal under Punxsutawney. Had the elevation of the "B" coal been desired, we should have added 200 feet to the 700, instead of 40, or, subtracting 900 from 1,850 gives 950 feet above sea level as the actual elevation of the "B" coal at Punxsutawney.

The following table will therefore enable anyone to compute the actual elevation of the stratum in each quadrangle that has been used to contour on, and by using the intervals as given in the table of coals or the local descriptions, the approximate elevation of any other coal or stratum may be computed:

TABLE GIVING STRATUM UPON WHICH CONTOURS HAVE BEEN DRAWN IN THE FIELD NOTES OR DETAILED PUBLICATIONS, AND THE ASSUMED DISTANCE FROM THE PITTSBURG COAL TO THAT STRATUM.

	Feet.
Newcastle quadrangle, Middle Kittanning,	—700
Beaver quadrangle, Upper Freeport coal,	—550
(Ames limestone),	—260
Sewickley quadrangle, Ames limestone,	—260
Burgettstown quadrangle, Pittsburg coal,	0
Carnegie quadrangle, Pittsburg coal,	0
Claysville quadrangle, Upper Washington limestone,	+570
Amity quadrangle, Pittsburg coal,	0
Brownsville and Connellsville quadrangles, Pittsburg coal,	0
Rogersville quadrangle, Pittsburg coal,	0
Waynesburg quadrangle, Pittsburg coal,	0
Masontown-Uniontown quadrangles, Pittsburg coal,	0
Clarion quadrangle, Lower Kittanning coal,	—800
Kittanning and Rural Valley quadrangles, Vanport limestone,	—850
Elders Ridge quadrangle, Upper Freeport coal,	—700
Latrobe quadrangle, Pittsburg coal,	0
Indiana quadrangle, Upper Freeport coal,	—700
Punxsutawney quadrangle, Upper Freeport coal,	—700
Curwensville and Houtzdale quadrangles, Lower Freeport coal,	—750
Barnesboro-Patton quadrangle, Lower Freeport coal,	—750
Johnstown quadrangle, Lower Kittanning coal,	—850
Ebensburg quadrangle, Upper Freeport coal,	—750

In the above table the minus sign indicates that the amount given should be subtracted from the elevations given on the contour map; the plus sign indicates that the amount should be added.

Without discussing the structural details, certain general features are readily apparent and need only be referred to.

First, there is the general northeast-southeast trend of the folds. While not nearly so straight as they have frequently been represented, nevertheless, taking large distances, the folds in this part of the State tend to have axes running about N. 30° E. On the south line of the State the trend is more nearly north, running from N. 20° E. to N. 25° E. Toward the northern part of the map there is marked bending to the eastward, until in the northeast corner of the area mapped the axes have directions of from N. 35° E. to N. 60° E. Had the map therefore been continued farther to the north and east, the general trend would have been more to the east, possibiy as high as N. 45° E.

In the *second* place there is noted a marked change from the closely folded anticlines and synclines of the southeast to the open gentle folds of the northwest, until to the northwest of Pittsburg the structure is little more than an irregular, very gentle slope in which some parts project very slightly beyond adjacent parts. So gentle is much of the structure at the northeast that, except for the spirit-leveled elevations to which it was everywhere referred, it would hardly have been possible to have detected any variations at all from a uniform slope, and the structure might have been drawn in with a ruler; and yet the work in oil and gas has shown that in many cases even these slight irregularities in the slope seem to have had a marked effect on the position of the oil and gas pools.

In the *third* place it will be noted that the folds are, as it were, but wrinkles on the surface of a broad syncline, of which the axis runs southwest and northeast through Pittsburg. South of Pittsburg this axis coincides with the axis on the Ninevah syncline and farther north with the axis of the Fairmount syncline. Thus at the southeast the position of the Pittsburg coal is theoretically on the Dulany anticline, 4,200 feet above sea level; on the Fayette anticline 1,800 feet above sea level; on the Belle Vernon anticline 1,050 feet above sea level; on the Amity anticline, the same, and in the Ninevah syncline it gets down to less than 100 feet above sea level. This is possibly even better brought out by a line through Indiana. Thus starting 10,000 feet above sea level in the southeast corner of the Ebensburg quadrangle, the Pittsburg coal even in the Pavia syncline does not get below 4,200 feet above sea level; in the deep Wilmore basin to the northwest it gets down to 1,700 feet; west of that it keeps above this elevation until the Laurel Hill axis is crossed where it has a maximum elevation of 3,900 feet above tide, though to only 2,800 feet in the line being followed. From the Laurel Hill anticline to Indiana the synclines carry the coal below 2,000 feet, and the anticlines raise it above 2,500 feet. The Latrobe syncline carries the coal down to 1,700 feet at Indiana and still lower farther south. The Elders Ridge syncline carries it down to 1,500 feet and down to 1,110 feet farther south. The Greenville anticline can only raise it to 1,600 feet in the line here followed, though nearly 2,300 feet farther north, while in the Fairmount syncline the Pittsburg coal south of Kittanning is only 1,550 feet above tide.

In the *fourth* place it is to be noted that in the center of the major synclinal axis there is a general rise of the structure in the direction of the axes of folding to the northeast. Thus in the axis of the major syncline it will be noted that in the southwest corner of the State the Pittsburg coal is almost down to sea level—locally within 100 feet of it. Going toward Pittsburg the strata in the center of the basin rise as in climbing toward the point of a spoon until at Pittsburg the coal of that name is 1,000 feet above sea level. Going northeastwards the same rise continues until in the Clarion quadrangle in the lower part of the major basin, the Pittsburg coal is theoretically over 2,000 feet above sea level. If the Uniontown syncline be followed it will be found near Uniontown to bring the Pittsburg coal down to 550 feet above tide. At Latrobe the coal is not below 700 feet; at Blairsville about 1,000 feet; at Indiana it is 1,700 feet above tide. This tendency to rise to the northeast does not continue southeast of the Chestnut Ridge, and in many parts of that area may be reversed. Thus in the Uniontown quadrangle the position of the Pittsburg coal on Chestnut Ridge is about 4,000 feet; east of Latrobe less than 3,500 feet; east of Indiana only 2,500 feet, and but little higher east of Punxsutawney.

In the first syncline east of Chestnut Ridge the Pittsburg coal is theoretically above 2,100 feet on the Uniontown sheet. East of Indiana it is down to 1,900 feet, but on the Curwensville sheet it ranges between 2,000 and 2,350 feet, so that the theoretical strike follows the axis of the folds. The Laurel Hill anticline east of the west edge of the Johnstown quadrangle has raised the Pittsburg coal theoretically to 3,900 feet; in the northern part of the quadrangle it is down to 2,800 feet and at Coalport to 2,400 feet; eastward on the Houtzdale quadrangle it rises to 2,900 feet again. In the Johnstown syncline, and in the Bradley, Mud Lick and Houtzdale synclines the coal keeps not far from 2,000 feet.

Fifth, it emphasizes as has never been done before the undulating character of the folds in the direction of the axes. No such even-crested anticlines or even-bottomed troughs or synclines as have usually been pictured have been found to exist in the area covered by the map. Instead the synclines appear to be a series of elongated or oval or spoon-shaped basins separated by relatively high divides or buckles; and the anticlines consist of elongated or oval domes or crests separated by low "sags" as they may be called. A study of the relative position of these basins and crests brings out some interesting points. In the Uniontown-Connellsville quadrangles the basins and crests are set in alternate arrangement, while in Cambria county they are opposite. Thus, for example, the Uniontown basin is not opposite the highest part of the crests of the adjoining anticlines, but opposite the sags of those anticlines, and *vice versa.* In Cambria county, on the other hand, it will be noted that the highest part of the Ebensburg anticline is almost exactly between the lowest parts of the Wilmore and Johnstown basins adjoining it on either side. This is even more strikingly shown in the Latrobe quadrangle where domes in Fayette and Chestnut ridges and basins in the Greensburg and Latrobe synclines all fall in a line nearly normal to the strike. The same thing is true in the Elders Ridge quadrangle, of the domes and basins in the Roaring Run anticline, Elders Ridge syncline and Jacksonville anticline. On the whole the opposite arrangement appears to be more common than the alternative, though not enough so as to be made the basis of a theory in the matter. In the case of the Latrobe quadrangle a line lying nearly normal to the structure through the points of maximum folding south and west of Latrobe, from the southeast corner of the quadrangle to the Greensburg syncline, would cross contour lines to the extent of 5,400 feet; one through the maximum folding south of Blairsville would cross 5,150 feet, while through the nodes between, a line would cross only 4,150 feet. Other cases are even more striking. A nearly east and west line a little north of Johnstown in crossing from the Wilmore syncline to the Laurel Hill anticline, would climb up 2,950 feet and down 750 feet or a total of 3,700. A parallel line through Ebensburg would climb up 900 feet and down not at all, making a total of 900 feet.

Unfortunately the areas not yet mapped prevent carrying this study out broadly. It should be noted, however, that in the cases cited that the lines passing over the greater amounts of ascent and descent in the structure are not proportionately longer than the other lines. The difference is made up in the difference in the steepness of the structural slope. Now it is a well known fact that a highly convex arch is longer than a lower arch of the same span. It would therefore appear that along certain lines transverse to the folding any selected rock stratum as folded is longer across the areas of maximum folding than the same rock is along other selected lines or what might be called nodal lines as they pass through the nodes of these undulating axes. This difference is probably not large. Calculation of the length of the Upper Freeport coal over the Chestnut Ridge anticline on a line southeast from Punxsutawney, as compared to the cord of the same arch, showed a difference of less than 5 feet, notwithstanding the rise of the arch at the center is 750 feet above the cord. The calculations in question seem to show that the shortening of the rocks due to folding in a line passing from the Allegheny Front northwestward through Punxsutawney was much smaller than would have been anticipated—not over 30 feet. Further south where the folding is more intense it would be much more. Time does not permit the following of the subject further at this time, as the whole subject of the mechanics of mountain-making soon become involved.

Another question is raised by observing these nodal lines and lines of maximum folding. Have there been axes of cross-folding action? This too will be passed by at this time. It is probable that the completion of the structure of Somerset county and of the breaks existing within the area already enclosed will be necessary before some of these questions can be examined with any satisfaction.

Fault Structure. On the map of the Houtzdale quadrangle which has been displaced and set into the lower part of the map there are shown faults of sufficient size to noticeably influence the structure contours. The faults shown are only a small part of those located. It must be admitted that in many cases the structure shown in connection with these faults is highly conjectural. In some cases the faults are on the mine maps so that the direction and downthrow can be accurately determined within the area of the mine map. In other cases the fault has been mined up to for short distances, sufficient to give its direction but not its extent, and often not its throw. In many cases information about the faults has been obtained entirely by report of mine superintendents and others, and a few of the faults have been inferred from conditions observed at the surface. On the other hand, many of the faults can be readily examined. As far as seen by the writer, all are of the normal type. The down-throw varies from 0 to 200 feet or more; the fault-plane is usually nearly vertical. Examination of the fault faces shows that the faulting movements were in a large measure horizontal, the horizontal element probably exceeding the vertical. The west side of the fault was dropped more frequently than the opposite side, though not enough so to make a rule. In studying these faults the writer has been led to compare them with other faults similarly placed with reference to the Allegheny Front as found in Virginia, Kentucky, Tennessee and Alabama. In all cases the faults appear close to the Allegheny Front, as though produced by the structure that uplifts that ridge. In the second place in some of the other areas it is much more pronounced than here; the faults instead of being parallel to the strike are partly normal to it, in most cases cutting the strike at an angle of about 45°. All of these facts have led the writer to conclude that these faults are the result of the rupturing of the rocks by the pressure which folded the rocks of this region, such rupturing having taken place in the lines of maximum stress, which in this case are at nearly 45° to the direction in which the pressure acted. Rupturing of this kind is seen in the spalling off of the angles of a block of building stone under great pressure or in the breaking of test blocks of building stone in the testing machine. That these faults probably extend up into the Allegheny mountains in the southeast corner of the quadrangle is a fair inference, but lacking knowledge to that effect, they are not so represented.

REVIEW OF ECONOMIC GEOLOGY OF SOUTHWESTERN PENNSYLVANIA.

The principal economic products of the region which has been covered by recent geologic work are coal, clay and shale and their products, sandstone and limestone, their importance being in the order named. Under this heading little more than the briefest sort of an abstract of the published reports will be given. For more details reference should be made to the reports on the various subjects for the area desired, which can be obtained from the chapter on bibliography. Somewhat more space is given to describing these resources in the quadrangles that have not been finally published upon than in the others. These resources will be considered in the order of their importance.

COAL.

General Statement. Coal has always been the largest single mineral resource of Pennsylvania. In a preliminary statement on the coal production of Pennsylvania in 1907 the Division of Mineral Resources of the U. S. Geological Survey states as follows regarding coal in Pennsylvania:

"Until 1902 Pennsylvania produced each year more than half the coal mined in the United States, but since then the State's output has fallen below one-half, by reason of the great increase in production in other states.

"Pennsylvania produces more coal than any other single state or country in the world except Great Britain, having in 1907 exceeded for the first time the production of Germany. Pennsylvania's production of coal exceeds, in fact, the combined production of all foreign countries except Great Britain and Germany.

"In the production of bituminous coal alone Pennsylvania far outranks any of the other states, the output in 1907 being nearly three times that of Illinois, which was the second coal-producing state, and exceeding the combined production of Illinois, West Virginia, Ohio and Alabama—145,801,602 short tons. One county in the State (Cambria) showed an increase of over 4,000,000 tons, and three others (Clearfield, Fayette and Indiana) each increased more than 2,000,000 tons. Four counties (Allegheny, Somerset, Washington and Westmoreland) showed increases of more than 1,000,000 tons each. Only one county (Lawrence) showed a decrease in production, and this loss was comparatively insignificant. The combined production of Fayette and Westmoreland counties, in which is located the famous Connellsville coking district, was over 58,000,000 tons, an amount larger by 7,000,000 tons than the total output of Illinois. Fayette county produced a little over 29,000,000 tons and Westmoreland county a little less than that quantity.

"Mr. M. R. Campbell, of the United States Geological Survey, estimates the amount of coal originally in the anthracite fields of Pennsylvania at 21,000,000,000 short tons and that in the bituminous fields at 112,574,000,000 short tons. It is said that, by the methods of mining anthracite coal in former years, for every ton of coal mined and marketed 1½ tons were either wasted or left in the ground as pillars for the protection of the workings, so that the actual yield of the beds was only 40 per cent. of the contents. This percentage of waste has now been materially reduced, but the exhaustion to the close of 1907 has probably amounted to about double the production, or 4,000,000,000 short tons. This would leave still in the ground approximately 17,000,000,000 tons, which would be capable of yielding, at the rate of 1 ton of coal lost for each ton mined, 8,500,000,000 tons, or approximately 100 times the quantity of anthracite produced in 1907.

"If we estimate for the bituminous production 1 ton of coal lost for every 2 tons mined, the exhaustion to the close of 1907 has been 2,760,000,000 tons, which would leave still in the ground in Pennsylvania a little less than 110,000,000,000 short tons of bituminous coal. The annual production and consumption of coal will no doubt continue to increase, but at the rate of production reached in 1907 the available supply in Pennsylvania would last about 490 years.

"Among the incomputable elements of the problems of the future of coal mining are the extent of the possible utilization of natural forces for power production and storage—such as wind, waves and waterfalls, and the sun's rays—and the cost of these as compared with that of coal. It is evident, however, that even if there shall be a greatly increased rate of production and consumption the Pennsylvania coal-mining industry will form a prominent factor in the country's mineral production for many years.

"In 1907 the total production was 235,925,749 short tons, having a spot value of $319,421,826. The production of anthracite was 76,432,421 long tons (equivalent to 85,604,312 short tons), having a spot value of $163,584,056. The production of bituminous coal was 150,321,437 short tons, having a spot value of $155,837,770.

"Compared with the aggregate production of 1906, which amounted to 200,575,617 short tons, valued at $262,208,345, the output in 1907 exhibits an increase of 35,350,132 short tons, or 17.6 per cent., in quantity. and of $57,213,481, or 21.8 per cent., in value. The increase in the production of anthracite coal was 12,787,412 long tons (equivalent to 14,321,901 short tons), or 20.1 per cent., in quantity, and $31,666,362, or 24 per cent., in value. In the production of bituminous coal the increase was 21,028,231 short tons, or 16.26 per cent., in quantity, and $25,547,119, or 19.61 per cent., in value.

"The prices of both anthracite and bituminous coal in Pennsylvania were higher in 1907 than in 1906. The average price of anthracite was $2.35 per ton, an increase of 5 cents; the average price of bituminous was $1.04 per ton, an increase of 4 cents. Although the quantity of bituminous coal produced was nearly twice that of the anthracite, the hard coal represented greater value than the soft.

"At practically all the mines in the bituminous district of Pennsylvania there was, during the greater part of the year, an unprecedented shortage of miners and other employes, as well as a marked shortage of railroad cars. It is believed, however, that even if there had been no scarcity of miners and cars many of the mines would have been compelled to run on reduced time, particularly in central Pennsylvania, as the production has increased so rapidly within the last few years that it would have required an even greater demand than existed in 1907 to keep all the mines running to their full capacity. The increase of nearly 35 per cent. in the production of Cambria and Clearfield counties and of 60 per cent. in that of Indiana county shows the extent to which the development in central Pennsylvania has progressed. The scarcity of cars enabled the producers to maintain prices during the summer at the highest level known in normal times, and the business was undoubtedly the most profitable that Pennsylvania operators had known during a summer season. With the monetary troubles in October the demand for coal fell off and prices naturally 'slumped,' the operators finding it difficult to market any but the highest and best-known grades."

The subject of coal will be discussed under the three headings: Quality of the coal, stratigraphy of the coal beds, distribution and local details.

Quality of the Coals. As compared with those of the United States as a whole, the coals of Pennsylvania are all of high grade; nevertheless there is a marked difference in the coals in different parts of the State. It is now universally agreed that coal has been derived from vegetable matter. Such vegetable matter originally consisted of carbon, hydrogen and oxygen, in roughly the proportion of one-half carbon and one-half hydrogen and oxygen, the hydrogen and oxygen being approximately in the ratio of 1 to 8, or the same as their ratio in water. Vegetable matter therefore might seem to be on the face of the analyses carbon and water, in the proportion of 1 to 1. In just what condition or combinations these elements exist in cellulose is not known though of course their relative proportions are definitely known. By heating wood slightly, not only is water driven off, but compounds of hydrogen and carbon that are combustible; in fact it is assumed beyond question, if not actually known, that cellulose is a compound or mixture of compounds of the elements carbon, hydrogen and oxygen, and not, as might appear, a hydrate of carbon. In the same way the methods used to determine the approximate composition of coal use heat, and by destructive distillation break the coal up into: first, water vapor; second, volatile matter, partly combustible and partly water vapor; third, uncombined carbon, and fourth, impurities. The fact that coal stored where not subjected to heat will give off volatile combustible matter, or gas, and the fact that repeated and varied analyses of coals by destructive distillation show correspondence in results within limited areas, suggest quite strongly that the volatile matter of the coal is in some way an inherent part of it. Indeed it is quite possible that in the lower coals at least, all of the carbon may be combined with the hydrogen and oxygen, and that it is only through our imperfect methods of analysis that it is left and appears to be uncombined. On that basis the coal is made up apparently of uncombined or fixed carbon, of volatile hydrocarbons and water, with impurities. Though the impurities may greatly affect the economic value of the coal, the essential differences in coals are due to differences in the proportion of the three constituents just mentioned.

A study of different coal fields shows that coals constantly tend to suffer loss of the volatile parts (as obtained by distillation)—the hydrocarbons and water—and as a consequence the carbon left behind form a larger and larger proportion of the coal remaining. This loss may be rapid, as when the coal bed is subjected to heat from an intrusion of igneous rock. Thus in many places in the Rocky mountains the coal beds have been converted into anthracites or natural cokes, due to a sheet of molten lava having intruded itself into the rocks through or near the coal bed. More often this loss is a very gradual one, being inappreciable except through long geologic ages. Further, it is found that this loss is accelerated by certain factors, the most notable of which is the folding of the rocks in the process of mountain making. Whether the change in this case is due to the heat generated by the friction of the folding rocks, as has commonly been assumed in the past, or whether, as argued by Rogers and more recently by Campbell, the folding of the rocks has tended to break them along innumerable minute planes, and these breaks have allowed the escape of the volatile matter, is yet a matter of question. Possibly both factors have been potent. That the coals and other rocks where highly folded are also highly fractured is a matter of common observation. When the folding and probable heating become intense, the fractures are recemented with practical loss of the original structure, as is well seen in anthracite coal.

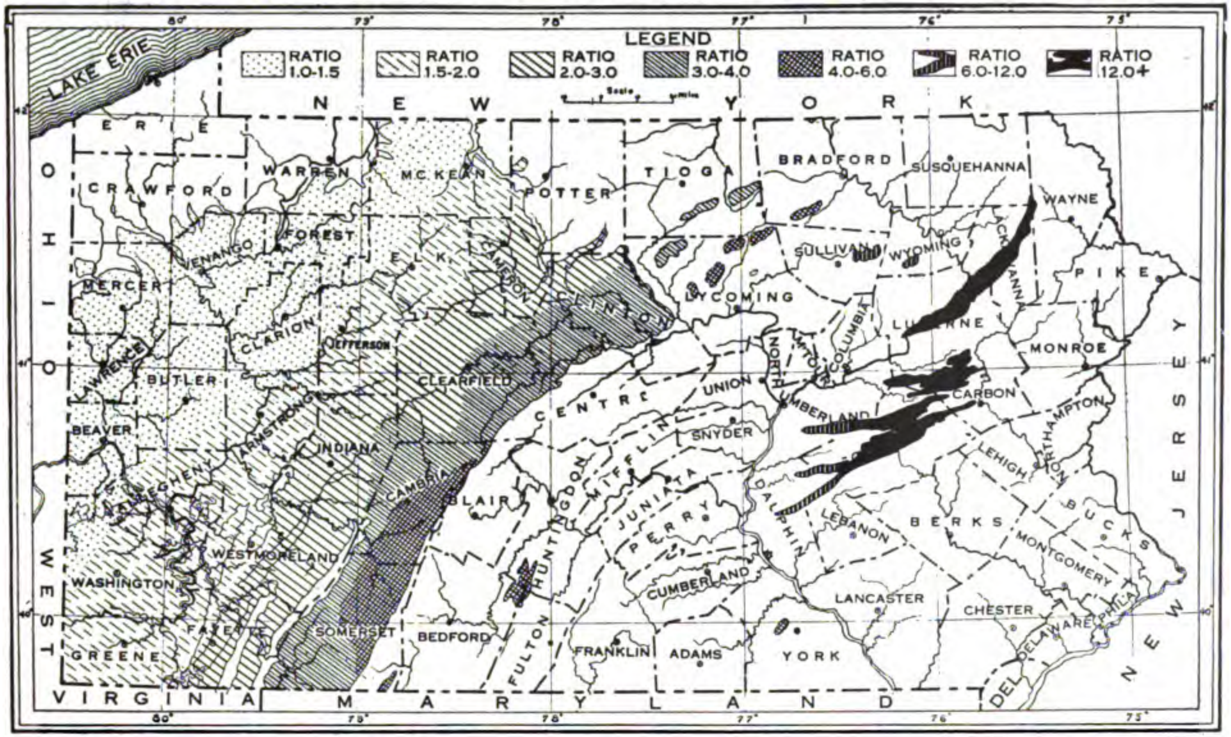
The classification of coals in the main is based on the proportion of the three parts given: fixed carbon, volatile combustible matter and water. It is generally assumed that there is no fixed carbon in wood. By present methods of proximate analysis an air-dried lignite may show from 20 to 33 per cent. of fixed carbon, the rest, excepting the impurities, being water and volatile hydrocarbons. In the subbituminous coals the fixed carbon will run from 30 to 50 per cent. of the whole; in bituminous coals from 40 to say 70 per cent.; in semi-bituminous from about 70 to 80; in semi-anthracites from 75 to 85, and in anthracites from 80 per cent. upward. For the higher coals such as those found in Pennsylvania, the method of classification in the past has been on the basis of the "fuel ratio." This is obtained by dividing the fixed carbon by the volatile combustible matter.

As stated, the volatile matter is carbon, hydrogen and oxygen. From the practical standpoint this acts as though composed of compounds of hydrogen with carbon, and water, for the oxygen and one-eighth of its weight of hydrogen apparently produce no heating effect in burning. That portion of the volatile matter is therefore called the "inert volatile matter." In lignite more than one-half of the volume of the volatile matter may be inert; in Illinois coal about 40 per cent. of the volatile matter is inert; in the semi-bituminous coals of Pennsylvania not more than one-fourth or one-fifth of the volatile is inert. To determine the inert portion of the volatile, however, requires an ultimate analysis. It has therefore been customary to determine the fuel ratio by dividing the fixed carbon by the total volatile matter driven off after the coal has been dried at 212° F.

Mr. Persifor Frazer, Jr., who is mainly responsible for this method of classification, adopted the following:

CLASSIFICATION OF PENNSYLVANIA COALS.

	Fuel ratio.
Anthracite,	100-12
Semi-anthracite,	12-8
Semi-bituminous,	8-5
Bituminous,	5-0



MAP OF PENNSYLVANIA, SHOWING DISTRIBUTION OF COALS BY FUEL RATIOS.

PLATE X.

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It is probable that present trade usage would make semi-anthracites from 10 to 6 and semi-bituminous from 6 to 4, or possibly 3.5.

An attempt has been made on Plate X to indicate the distribution of the various grades of coal in Pennsylvania on the basis of the fuel ratios. Examination of the map shows the anthracite coal of Lackawanna, Luzerne, Carbon and Schuylkill counties to have a fuel ratio averaging over 20, the analyses showing from 80 to 88 per cent. of fixed carbon and from 3 to 4.5 per cent. of volatile matter. The western ends of those fields tend to grade into the semi-anthracite class. In eastern Sullivan is the Bernice field of "soft anthracite" or semi-anthracite, with a fuel ratio of 6 to 10. This field contains coals that run over 80 per cent. of fixed carbon and under 9 per cent. of volatile matter, 83.4 of fixed carbon and 8.10 of volatile being a typical example. On the other hand most of the analyses on hand from the Bernice Basin show a fuel ratio of between 3.5 and 6. Then comes the Broadtop field of Bedford and Huntingdon counties, in which the eastern edge has a higher fuel ratio than the western, and a strip along the Allegheny Front, where the rocks, if not more folded than farther west, have probably been subjected to much greater stress. The rocks west of the Allegheny Front seem to have served as a buttress against which the rocks to the east were folded, and it is natural to suppose that the face of this buttress should suffer more severely than the rocks farther back. The folding is not always more noticeably pronounced close behind the front, but in Clearfield county at least mining has brought out the fact of extensive thrust faulting, and all of the coals near the face tend to be minutely dissected with fracture planes, making the coals tender and soft, so that there is found from Bradford county a strip running through Lycoming, southeast Clearfield, eastern Cambria and Somerset counties, where the coals have a fuel ratio of from 4 to 5. At South Fork in Cambria county the fuel ratio runs close to or quite to 6. West of that through the same counties, and extending over into Tioga and Clinton, the coals show fuel ratios of from 3 to 4. Coming between 2 and 3 will be found the coals of the Allegheny or Lower Coal Measures in Blair, Clinton, Indiana, Westmoreland and Fayette counties, and part of the Pittsburg coal, though only that portion in the basin immediately west of Chestnut Ridge, where it has been involved in relatively close folding. It is noticeable, for example, in Indiana county that while the Pittsburg coal in that county will run about 1.6, the Allegheny coals will run from 2.5 to 3. The Connellsville coking coal of Westmoreland and Fayette counties will as a rule run about 2, sometimes reaching as high as 2.5. As a rule, however, the Pittsburg coal will run between 1.5 and 2. In addition to the Pittsburg coal most of the coals of Potter, McKean, Jefferson, Armstrong, Butler, Allegheny and Washington counties will run between 1.5 and 2. The coals lying still farther to the northwest in Clarion, Mercer, Lawrence and Beaver, will run between 1 and 1.5. On the map the different symbols have not been drawn as sharp boundaries, nor are they intended to indicate the exact limits of the areas in which the different ratios hold, but only the approximate limits. In many areas the data is meager or wanting, and only a preliminary study of the matter can here be presented. In many cases analyses from the same district will show a marked difference in the fuel ratio, as has already been cited in the case of the Bernice semi-anthracite field. In most of those cases the plan has been followed on the map of indicating the higher fuel ratio where that appears to be predominant. The following table gives a selected series of analyses typical of the different counties. As far as possible recent analyses have been used. These differ from the old analyses mainly in the way the sample was taken. Too often the older analyses were made from samples of selected pieces of coal which were considered to be representative, but of which the analysis as compared with more recent analyses indicates that the personal element almost invariably resulted in the selection of a piece or pieces of coal above the average grade in purity. The more recent analyses have been made from samples obtained by cutting a vertical trench the whole thickness of the bed, with the exception of such paratings as it is found are omitted in the practical mining of that coal. The coal so obtained is caught upon an oil cloth, broken up small, thoroughly mixed, then quartered, the two opposite quarters being rejected, the other two again mixed, broken finer, then re-quartered, and the process continued until a sample having a volume of about one quart is obtained. This is then at once inserted in a can and sealed air-tight, in which condition it is sent to the laboratory for analysis. In some cases the samples were obtained from carload lots of the coal when such coal was being tested. In that case, the coal having been broken up fine, as it was carried to the testing bins in a bucket conveyor, a small shovelful was taken from every, say, fifth bucket and the sample so obtained quartered and cut down to a laboratory sample.

Selected Analyses of Coals to Illustrate the Variations in Different Parts of the Coal Field of Pennsylvania.

County.	Town or Township.	F. C.	V. H. C.	M.	A.	S.	Method of sampling.	Date.	Analyst.
Allegheny,	Bruce,	57.45	35.19	1.92	5.44	1.84	a	1905,	F. M. Stanton.
Allegheny,	Union,	59.13	34.10	0.41	5.20	1.12	c	Prior to 1884,	O. Wuth.
Armstrong,	Kittanning,	53.59	35.09	1.61	9.71	4.62	a	1903,	Geo. Steiger.
Armstrong,	Rayburn,	49.19	32.93	3.19	14.69	7.32	a	1903,	Geo. Steiger.
Beaver,	Pulaski,	50.173	38.870	2.270	6.365	2.322	c	Prior to 1878,	A. S. McCreath.
Bedford,	Broad Top,	76.720	16.515	.575	4.960	1.230	c	Prior to 1882,	A. S. McCreath.
Bedford,	Broad Top,	67.497	20.375	.610	7.935	3.583	c	Prior to 1882,	A. S. McCreath.
Blair,	Bennington,	61.843	27.225	1.400	6.930	2.602	c	Prior to 1877,	A. S. McCreath.
Bradford,	Barclay,	70.744	17.110	.770	10.600	.776	b	Prior to 1878,	A. S. McCreath.
Butler,	Lancaster,	42.661	40.220	1.300	13.415	2.404	c	Prior to 1878,	A. S. McCreath.
Butler,	Winfield,	50.83	36.19	2.20	10.78	3.35	c	1903,	E. C. Sullivan.
Cambria,	Hastings,	66.09	21.79	4.25	7.87	1.59	a		F. M. Stanton.
Cambria,	Moxham,	75.73	13.77	0.75	9.75	1.92	a	1906,	F. M. Stanton.
Cambria,	South Fork,	79.65	15.95	0.65	3.75	0.78	a	1906,	F. M. Stanton.
Carbon,	Mauch Chunk,	83.813	4.275	3.087	8.184	.641	b	Prior to 1883,	A. S. McCreath.
Carbon,	Mauch Chunk,	87.982	4.125	3.008	4.379	.506	b	Prior to 1883,	A. S. McCreath.
Centre,	Rush,	64.082	24.360	0.640	7.540	3.378	c	Prior to 1874,	A. S. McCreath.
Clarion,	Clarion Junction,	51.95	39.11	1.69	7.25	4.11	a	1906,	F. M. Stanton.
Clarion,	Rimersburg,	50.63	31.70	2.07	15.60	1.66	a	1906,	F. M. Stanton.
Clarion,	Sligo,	55.79	34.49	1.72	8.00	2.23	a	1906,	F. M. Stanton.
Clarion,	Strattonville,	54.86	34.86	1.89	8.39	1.87	a		F. M. Stanton.
Clearfield,	Burnside,	64.09	25.14	1.19	9.58	2.52	a	1907,	F. M. Stanton.
Clearfield,	Woodward,	74.023	20.640	.810	4.020	.507	c	Prior to 1874,	A. S. McCreath.
Clearfield.	Sterling,	74.779	20.090	.765	3.700	.666	c	Prior to 1874,	A. S. McCreath.
Clinton,		67.801	20.845	.550	10.145	.659	c	Prior to 1860,	A. S. McCreath.
Elk,	Bensinger,	49.416	40.585	.990	5.640	3.369	c	Prior to 1885,	A. S. McCreath.
Fayette,	Connellsville,	59.84	29.97	2.82	7.37	1.22	a		F. M. Stanton.
Fayette,	Springfield,	65,596	24.545	0.930	8.155	1.414	c	Prior to 1878,	A. S. McCreath.
Fulton,	Wells Valley,	78.884	16.220	635	3.475	.826	c	Prior to 1882,	A. S. McCreath.
Greene,	Dunkard,	59.051	36.490	1.030	2.610	0.819	c	Prior to 1876,	A. S. McCreath.
Greene,	Cumberland,	51.582	32.344	1.180	13.588	1.306	c	Prior to 1876,	S. A. Ford.
Huntingdon,	Carbon,	73.091	16.002	.560	9.232	1.115	c	1876,	A. S. McCreath.
Huntingdon,	Carbon,	71.898	15.910	.535	8.223	3.434	c	1876,	A. S. McCreath.
Indiana,	Banks,	67.56	24.55	.99	6.90	.68	a	1907,	F. M. Stanton.
Indiana,	Canoe,	62.15	27.34	1.40	9.11	1.92	a	1907,	F. M. Stanton.
Indiana,	Young,	50.850	36.940	1.040	9.705	1.465	b	Prior to 1878,	A. S. McCreath.
Jefferson,	Winslow,	62.464	31.610	1.040	4.150	.736	c	Prior to 1878,	A. S. McCreath.
Jefferson,	Young,	66.78	27.86	1.19	4.17	.84	a	1907,	F. M. Stanton.

Selected Analyses of Coals—Continued.

County.	Town or Township.	F. C.	V. H. C.	M.	A.	S.	Method of sampling.	Date.	Analyst.
Lawrence,		49.823	42.445	1.930	3.970	1.832	a	Prior to 1879,	A. S. McCreath.
Lawrence,	Shenango,	54.163	41.210	2.100	1.940	.587	c	Prior to 1879,	A. S. McCreath.
Luzerne,	Wilkes-Barre,	83.967	4.342	2.494	8.544	.653	b	Prior to 1883,	A. S. McCreath.
Luzerne,	Hazle,	85.319	3.242	3.862	7.044	.533	b	Prior to 1883,	A. S. McCreath.
Lycoming,	McIntre,	72.474	15.825	1.220	9.845	.636	c	Prior to 1880,	A. S. McCreath.
Lycoming,	Pine,	64.063	22.985	3.830	8.545	.577	c	Prior to 1880,	A. S. McCreath.
McKean,	Sergeant,	44.561	38.710	1.470	10.420	4.839	c	Prior to 1880,	A. S. McCreath.
Mercer,	Shenango,	53.875	35.300	3.790	6.360	.675	c	Prior to 1879,	A. S. McCreath.
Potter,	Eulalia,	54.276	34.185	1.150	9.330	1.059	c	Prior to 1880,	A. S. McCreath.
Schuylkill,	Schuylkill,	86.611	3.718	3.320	5.933	.423	b	Prior to 1883,	A. S McCreath.
Schuylkill,	Schuylkill,	77.986	4.684	2.706	13.740	.884	b	Prior to 1883,	A. S. McCreath.
Schuylkill,	West,	80.868	3.978	3.410	11.232	.512	b	Prior to 1883,	A. S. McCreath.
Somerset,	Border Station,	74.06	15.36	0.69	9.89	4.55	a	1906,	F. M. Stanton.
Somerset,	Kimmelton,	70.12	17.75	.50	11.63	2.10	a	1905,	F. M. Stanton.
Somerset,	Quemahoning,	70.632	15.415	.600	11.605	1.748	c	Prior to 1877,	A. S. McCreath.
Sullivan,	Cherry,	83.344	8.100	1.295	6.230	1.031	b	Prior to 1880,	A. S. McCreath.
Sullivan,		67.362	15.270	4.130	12.715	.523	c	Prior to 1880,	A. S. McCreath.
Sullivan,	Cherry,	54.099	21.410	7.930	16.010	.551	c	Prior to 1880,	A. S. McCreath.
Tioga,	Bloss,	64.306	20.640	.940	13.200	.914	c	Prior to 1878,	A. S. McCreath.
Tioga,	Bloss,	63.428	18.790	1.110	16.070	.602	c	Prior to 1878,	A. S. McCreath.
Tioga,	Wood,	71.326	17.975	2.820	7.245	.634	c	Prior to 1878,	A. S. McCreath.
Washington,	Anderson,	55.83	37.20	1.70	5.27	1.13	a	1904,	E. E. Somermeier.
Westmoreland,	Herminie,	58.71	32.21	1.11	6.27	.99	a		F. M. Stanton.
Washington,	Ellsworth,	59.60	33.97	1.53	4.90	.74	a	1905,	F. M. Stanton.
Westmoreland,	Greensburg,	58.74	30.83	1.15	9.28	1.85	a	1905,	F. M. Stanton.
Westmoreland,	Ligonier,	64.90	21.30	.92	12.88	2.15	a	1905,	F. M. Stanton.
York,	Liverpool,	74.358	18.482	4.310	2.322	.528	c		

Stratigraphy of Coals. Under the general head of stratigraphy the various coals and the accompanying rocks have been briefly discussed. It may however be of value here to present a list of the coals with somewhat of their thickness and distance apart.

TABLE OF COALS IN PENNSYLVANIA AND THE INTERVALS BETWEEN THEM.

- Dunkard Series.
  - Greene formation.
    - Coal, Windy Gap, (+1,500 feet above Waynesburg coal) Thickness?
    - Coal, Ninevah, 1 ft. 8 in., 1 ft. 6 in.
      - Interval, 110-140 ft.
    - Coal, Hostetter, 1 ft. to 15 in.
      - Interval 30 to 40 ft. (?)
    - Coal, Dunkard, 1 ft. 6 in., 1 ft.
      - Interval 125 ft.
    - Coal, Ten-mile (Sparta) 1 ft. 8 in.
      - Interval 60 ft.
    - Coal, Upper Washington, 0 to 14 inches.
  - Washington formation.
      - Interval 70 ft.
    - Coal, Jollytown.
      - Interval 80 ft.
    - Coal, Washington "A," 0 to 5 ft.
      - Interval 70 to 80 ft.
    - Coal, Washington, 0 to 10 ft.
      - Interval 12 to 15 ft.
    - Coal, Little Washington, 0 to 1 ft.
      - Interval 30 ft.
    - Coal, Waynesburg "B" 1 to 2 ft.
      - Interval 40 ft.
    - Coal, Waynesburg "A," 0 to 4 ft.
      - Interval 50 to 80 ft.

- Pennsylvanian series.
  - Monongahela formation.
    - Coal, Waynesburg, 3 to 10 ft. (270 ft. above Pittsburg bed).
      - Interval 20 to 45 ft.
    - Coal, Little Waynesburg, 0 to 1 ft.
      - Interval 60 ft.
    - Coal, Uniontown, 0 to 3 ft.
      - Interval, 116-126 ft.
    - Coal, Sewickley, (upper and lower locally) 0 to 6 ft. to 30 ft. (Mapleton, Meigs Creek coal).
      - Interval 70 ft.
    - Coal, Redstone, (Pomeroy bed of Ohio) 0 to 5 ft.
      - Interval 30 to 80 ft.
    - Coal, Pittsburg, 5 to 22 ft.
  - Conemaugh formation.
      - Interval 25 to 60 ft.
    - Coal, Little Pittsburg, 1 to 2 ft.
      - Interval 75 to 100, (below Pittsburg 100 to 125).

Coal, Little Clarksburg (Bavington?)
  Interval 75 ft.
Coal, Elk Lick (Barton).
  Interval 25 ft.
Coal, Harlem, (Friendsville, Crinoidal, Platt).
  Interval 75 to 90 ft.
Coal, Bakerstown, 0 to 5 ft.
  Interval, 90 to 125 ft.
Coal, Gallitzin, (Brush Creek, Masontown, Mason, Farmington) 0 to 4 ft.
  Interval 50 ft.
Coal, Mahoning, 0 to 5 ft.
  Interval 40 to 70 ft.

Allegheny formation.

Coal, Upper Freeport ("E" "Cap" "Lemon" "Coke Yard") 0 to 16 ft., 3 to 5 ft.
  Interval 20 to 65 ft.
Coal, Lower Freeport ("D," Moshannon) 0 to 16 ft., 2 to 7 ft.
  Interval, 35 to 70 ft.
Coal, Upper Kittanning ("C," "Pot" bed, cannel bed, cement bed) 0 to 14 ft., 1 to 2 ft., 70 to 110 ft. below Upper Freeport.
  Interval, 10 to 30 ft.
Coal, Gorman, 0 to 4 ft. (local.)
  Interval 10 to 30 ft.
Coal, Middle Kittanning (C) 0 to 6 ft.
  Interval 15 to 30 ft.
Coal, Darlington ("B") 0 to 4 ft.
  Interval 15 to 20 to 40 ft.
Coal, Lower Kittanning ("B," Miller) 2 to 6 ft. 200 ft. below Upper Freeport.
  Interval 3 to 20 ft.
Coal, Lower Kittanning, 0 to 3 ft. (under bench).
  Interval 10 to 60 ft.
    Vanport limestone.
  Interval 0 to 30 ft.
Coal, Scrubgrass, (Upper Clarion) 0 to 3 ft.
  Interval 0 to 35 ft.
Coal, Clarion, 0 to 4 ft.
  Interval, 10 to 40 ft.
Coal, Brookville, 0 to 6 ft. 60 to 120 ft. below Lower Kittanning.

Pottsville formation.

  Interval 40 to 70 ft.
Coal, Upper Mercer (Mt. Savage) 0 to 4 ft.+
  Interval 5 to 20 ft.
Coal, Lower Mercer, 0 to 4 ft.+
  Interval 50 to 100 ft.
Coal, Quakertown, 0 to 4 ft.
  Interval 70 to 150 ft.
Coal, Sharon, 0 to 5 ft.
Coals of Pocono age.

DISTRIBUTION AND LOCAL DETAILS.

PITTSBURG DISTRICT.

Describing the coal of the Burgettstown, Carnegie, Claysville, Amity, Brownsville, Connellsville, Rogersville, Waynesburg, Masontown and Uniontown quadrangles.

The great body of the Pittsburg coal in Pennsylvania is contained in the quadrangles named and in the Pittsburg and Greensburg quadrangles which have not yet been studied. These quadrangles cover almost all of Washington, Greene, southern Allegheny, western Fayette and western Westmoreland counties. Very similar conditions exist over all of these quadrangles, and to save repetition they will be considered together. As the Pittsburg coal has long been known, and as it is planned that when this field has been entirely covered a single comprehensive volume will be prepared on it, only a very brief summary of the coal resources of this area will be given here.

PITTSBURG COAL.

The present commercial value is given to this field almost entirely by the Pittsburg coal. It may therefore very properly be treated first. The great value of the Pittsburg coal is due to two things: its quality and its minability.

Quality. The quality of the Pittsburg bed differs considerably in different parts of the field even in Pennsylvania. This is strikingly seen if comparison be made between the coal from Connellsville and that from western Washington county. Practically all of the coal is good steam coal. Part of it is a high-grade gas coal, but its most valuable part is that portion from which can be made high grade coke.

Starting at the east outside of the area here considered, the Pittsburg coal occupies a limited area in the Salisbury basin in southeastern Somerset county. Here the coal has a fuel ratio of about 3.5. Analysis shows it to have about 70 per cent. of fixed carbon, 20 per cent. of volatile combustible matter, 8 per cent. of ash, .75 per cent. of sulphur and 1.25 per cent. of moisture. Coming westward a small basin of the Pittsburg coal is found in eastern Westmoreland county in the Ligonier Valley, at Ligonier. This is east of the Chestnut Ridge anticline. Here the coal shows a fuel ratio of a little under 3. Analyses will show about:

Fixed carbon,	62 per cent.
Volatile hydrocarbons,	23 per cent.
Ash,	12 per cent.
Sulphur, less than,	2 per cent.
Moisture (air dried) less than,	1 per cent.

Crossing the Chestnut Ridge anticline, the fuel ratio drops to about 2, the fixed carbon becoming about 60 per cent., the volatile hydrocarbons about 30, the ash 8, the sulphur 1 or less, the moisture (air dried) 1 or over. Here is the first large body of coal preserved and here is the great Connellsville-Uniontown coking district.

Continuing westward or northwestward, the Fayette anticline is crossed. This is the last of the sharply folded anticlines, and west of it the structure becomes gently and irregularly folded. Correspondingly, west of that anticline the coals have not lost so large a proportion of their volatile constituents. The fuel ratio in the Pittsburg bed will there usually run under 2, and will average about 1.6. Thus most of the analyses will run from 50 to 60 per cent. of fixed carbon and from 30 to 37 per cent. of volatile matter. The ash runs rather high, usually from 10 to 12 per cent., and the sulphur usually between 1 and 2 per cent. Locally the ash runs down to 6 or 7 per cent. and the sulphur will run under 1 per cent.

Crossing the Monongahela river into Greene county, analyses indicate about the same grade of coal, some of the analyses giving a fuel ratio as high as 2 or even a little over, but averaging between 1.6 and 1.7. The percentage of ash is the same or lower and of sulphur about 1.

In southeastern Washington county similar conditions hold. Analyses of the Ellsworth mines show from 53 to 59 per cent. of fixed carbon, and from 33.5 to 37 per cent. of volatile matter. The same analyses show from 4 to 8 per cent. of ash and from .73 to 1.61 per cent. of sulphur. Toward the northwest part of Washington county the Pittsburg coal shows a marked increase in the percentage of sulphur, some of the analyses showing as high as 4 per cent. or over.

The Coal Bed. Apparently within the line of its outcrop the Pittsburg coal is a continuous bed. As the coal in a large part of this area is deeply hidden, it is impossible to assert that there will not be some areas possibly of some size where the coal is lacking. At the east the roof of the coal is usually shale. West of the Monongahela the Pittsburg sandstone becomes more prominent. As it does so it is found to occupy an old eroded surface. This erosion has in many places cut out the roof division and the strata intervening between that and the main division, and has cut somewhat into the main or lower division. While mining or close prospecting has not yet developed any area in which this down-cutting has cut entirely through the coal or removed it, as far as known to the writer, it is not improbable that such removal will be developed in the future. Areas in which the Pittsburg coal is known to be lacking are well known in Ohio and West Virginia, and it is not unreasonable to expect that similar though probably smaller areas may be found to contain no coal in Pennsylvania.

The coal bed itself is readily divisible into two parts, the upper of which is known as the roof coal or division, and the lower as the main coal or division. Between them is the over-lay or main clay. In parts of the area the two divisions, which are usually separated by only a foot or less, become separated by 15 or 20 feet. Then sandstone or shale as well as clay are found between the two divisions.

The roof division has its best development at the north and in general thins to the south. In northern Washington county it attains dimensions allowing its working independently of the lower division, while in northern West Virginia it is usually lacking or thin. At the north it will measure from 5 to 6 feet in thickness. It is everywhere characterized by its clay partings. These are often extremely irregular so that detailed measurements made a few yards apart will sometimes give entirely dissimilar sections. This irregularity is well shown in fig. 19 from a sketch made to scale near Woodside. In places the clay beds become more regular. In some sections the division is less than one-half coal, in others the clay forms one small parting. In the main, the roof division has been considered worthless and left in the mine. It now seems possible that in the not distant future it may be removed in mining and utilized in the manufacture of producer gas. The partings in the roof division are sometimes clay, sometimes shale and frequently bone.

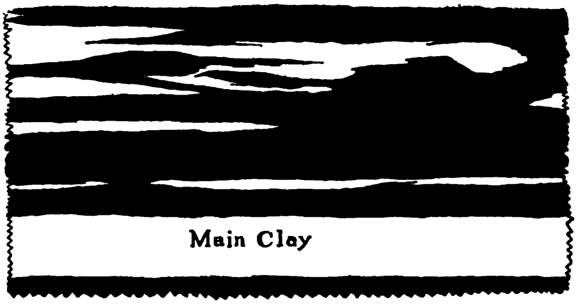

Fig. 19. Sketch of part of an outcrop of the upper division of the Pittsburg coal near Woodside; to illustrate the irregular character of the clay partings in the division, (G. H. A.)

The main clay or "over-clay" is usually an impure clay, often with coal streaks, especially near the base. It will average a little under a foot. The lower division contains four benches as is shown in the following general section of the Pittsburg coal:

DIVISIONS OF THE PITTSBURG COAL.

	Feet	Inches.
Roof division,	2-8	
Main or "over-clay," about,	1	
"Breast" or "main" bench, often with parting in the middle,..	2-10	
Parting,		¼
"Bearing in,"		4-6
Parting,		¼
"Brick" bench, about,	1	
Parting, often absent or thin.		
"Bottom" bench,		12-20

The breast or main coal bench is the most valuable and important part of the bed. It varies in thickness from 2 feet in Ohio to 3 feet at Pittsburg, 6 feet at Brownsville, to as high as 10 feet in the Georges creek region of Maryland. The top of the breast coal for a few inches is harder than the rest, often cannelly and frequently bony. There is occasionally a thin parting near the middle of this bench, especially toward the northwest.

The "bearing-in" bench which in pick mining is mined in in undercutting the breast coal is a remarkably regular feature of the bed, especially with its two bounding thin shale partings above and below. The partings are usually gray mottled from ¼ inch to 1 inch thick. To the south they become bony and less conspicuous. The coal bench is a bright, pure coal from 3 to 6 inches thick. The brick coal, named from the brick-like shape of the blocks into which it mines, runs from 0 to 1 foot thick. The parting between this and the bottom bench is often inconspicuous and sometimes lacking.

The "bottom" bench is 12 to 25 inches thick and usually impure. The writer hopes the present season to examine this coal in the erosion channels south of Pittsburg and expects in those channels to find that this bottom bench has greatly thickened up. This is often left on account of its impurities. It could be utilized with the roof coal if that ever should be used.

Considering the coal as a whole, the lower or working division has a thickness near Pittsburg of about 5 feet. Going southward this increases so that over the southwestern part of the State it will probably average 7 feet, ranging from 6 to 8 feet over much of Greene and Fayette counties.

Distribution. The distribution of the coal bed is indicated on the large map, also for handy reference in the accompanying fig. 20. The small areas in the Salisbury and Ligonier basins lie outside the area mapped at this time, as do also the areas in the Greensburg and Pittsburg quadrangles. West of the Chestnut Ridge anticline is the Uniontown-Connellsville basin; a division of the Fayette anticline to the north incloses the Greensburg basin in which is a considerable body of coal; beyond that the coal forms a solid body, except where broken up by topography. This main body lies in a great basin. The center of it lies in a line from Pittsburg to the southwest corner of the State, deepening in a southwest direction. In the center of the basin in southwestern Greene county the Pittsburg coal is buried to a depth of about 1,500 feet. As it rises to outcrop at the north and northeast, it reaches daylight first where anticlinal rolls and domes cross the larger streams, until in the northern part of the Burgettstown and Connellsville areas it is entirely above drainage and takes the shape of the hills. It continues to rise in those directions until finally it is only to be found in the hilltops. North of the two quadrangles mentioned it occurs only in the hilltops in areas as a rule too small

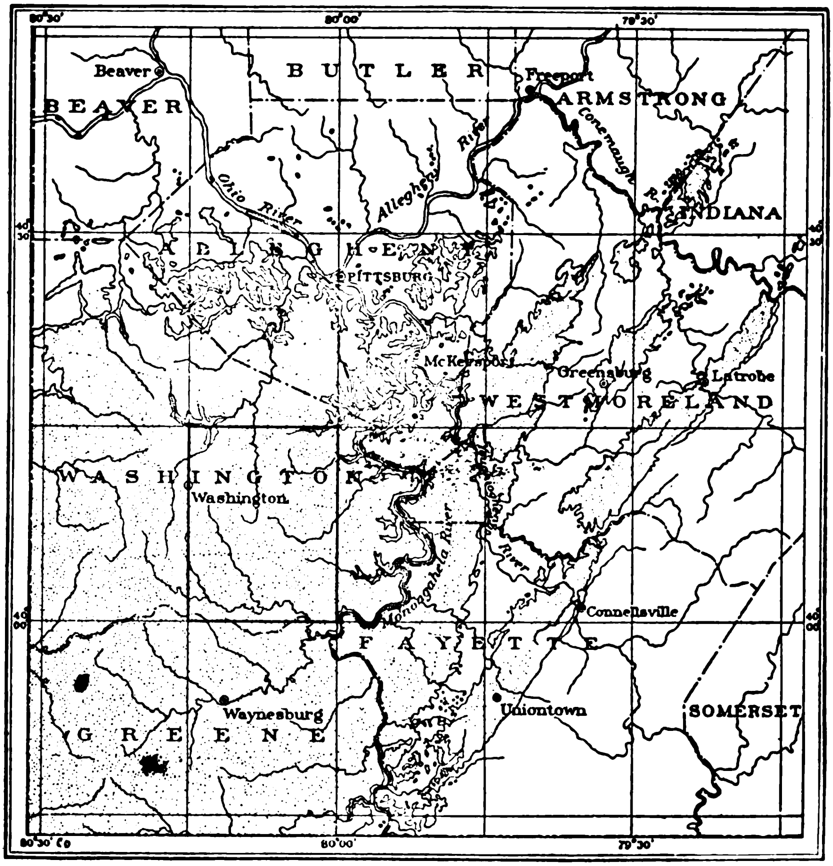

Fig. 20. Map showing area of the Pittsburg coal bed in Pennsylvania.

to serve any but neighborhood use. Reference should be made to the published reports for details on the stratigraphy, structure and position of the coals.

COALS ABOVE THE PITTSBURG BED.

(Same Quadrangles).

In general the coals above the Pittsburg bed do not hold out great promise of future value. It is true that in many cases they have a thickness equal to that of the Pittsburg bed, but they are unsually irregular or thin. They are usually broken into a number of benches by partings that sometimes make up half of the bed, and analyses shows that in most cases they run high in ash and sulphur.

Redstone Coal. The Redstone coal has a thickness of from 0 to 5 feet. It reaches from 3 to 5 feet in many places in the Uniontown syncline, coming about 80 feet above the Pittsburg coal. In general this coal is wanting or thin or is represented only by a few inches of black shale.

Sewickley Coal. The Sewickley coal reaches a thickness of 5 feet in many places as at Mapletown, Fair Chance, Brownfield and Lick Run near Gray's Landing, and it shows a thickness of 7 feet 6 inches below Gray's Landing. The partings thicken up until at one point the bed has spread over a space of 33 feet 6 inches. Outside of the regions mentioned it is usually thin or wanting. The shaft sections and drillings unite to indicate great irregularity in its thickness and in its vertical position. In some shafts and drillings it does not appear at all, while it will show a fair thickness in neighboring holes. It usually shows 3 to 4 per cent. of sulphur and is high in ash.

Uniontown Coal. At Uniontown the Uniontown coal has a thickness of 2 feet 3 inches. In the Leith shaft it has a thickness of 4 feet 6 inches. In most of the shaft sections it is entirely wanting or very thin. At Mapletown it is 5 to 6 feet thick including only 2 to 3 inches of clay near the middle. It is here a high grade free-burning block coal, highly prized for domestic use.

Waynesburg Coal. In the Uniontown syncline this coal has an average thickness of 3 feet 6 inches. West of this it has a much greater thickness but is usually split up with clay partings. Single benches range from 2 feet to 4 feet 6 inches at the best. Often by the removal of less than 1 foot of clay 5 to 6 feet of coal can be obtained. On account of this thickness—often over 10 feet— this coal makes very prominent showing in the roads and elsewhere, but its high ash and sulphur and numerous clay partings render it a non-commercial proposition as long as the Pittsburg bed remains. A sample from Greene county showed: 12.81 per cent. ash; 3.77 per cent. sulphur. It has its best development in Greene county where it yields 5 to 6 feet of coal. Before the discovery of oil and gas in that county this bed was quite extensively mined around Waynesburg for the local trade. The best sections there will show:

Coal,	2 feet.
Clay,	1 foot.
Coal,	3 feet.
Total,	6 feet.

It is still mined to some extent for local use. At this point it will run about 50 per cent. fixed carbon, 32 per cent. volatile matter, 1.2 to 3 per cent. sulphur, 11 to 13 per cent. ash.

In the Amity quadrangle the Waynesburg coal with a total thickness of 0 to 7 feet, usually has a middle bench of 2 feet. It is there a hard, block coal of no value for coke as shown by analysis. About 46 per cent. of fixed carbon, 32 per cent. of volatile matter, 10 to 20 per cent. of ash, 2 to 5 per cent. of sulphur, and 2 to 3 per cent. of moisture.

Waynesburg "A" Coal. While not as thick as the Washington coal, the Waynesburg "A" coal is probably the most valuable in the Dunkard formation. It shows a thickness of 3 to 4 feet 6 inches locally with in general a thickness of under 2 feet. It will be of value only when the larger underlying beds are exhausted.

Washington Coal. The Washington coal is often thick but is usually so broken up with partings as to be nearly or quite worthless. It shows its best development in Washington county where it reaches a thickness of up to 7 feet, but of this the thickest bench is not more than 2 feet 9 inches. In western Greene county it has a total thickness of 2 to 4 feet, but over most of Greene county is only 18 inches to 2 feet thick. Recent analysis shows:

Fixed carbon,	40.96 per cent.
Volatile hydrocarbons,	36.79 per cent.
Ash,	14.03 per cent.
Sulphur,	3.79 per cent.

At Ten-mile village is found the Ten-mile coal with a thickness of from 1 foot to 3 feet 2 inches.

COALS BELOW THE PITTSBURG COAL.

Of more interest and probably of much more value than the coals last described are the coals below the Pittsburg bed. Unfortunately our knowledge of them is very meagre. They outcrop to the east of the Uniontown syncline and are commonly reported in drillings made for oil and gas, though apparently no systematic attempt has been made to explore for them through any part of the Monongahela river basin where they are below drainage. As long as the Pittsburg coal can be mined from an outcrop along the river there will be little inducement to explore for lower coals. As, however, the Pittsburg coal becomes exhausted from separate holdings it would seem to the writer that some knowledge of the character, quality and thickness of the underlying coals would perhaps be desired before moving the plant to new areas of the Pittsburg bed. With the increasing value of lands underlain by the Pittsburg bed and the gradual exhaustion of the most easily available Pittsburg coal, it is only a question of a few years when inquiry will be directed to the underlying coals of Allegheny age. It is unfortunately true that where they outcrop on the east side of this district these lower Allegheny coals resemble the coals above the Pittsburg, being usually much broken up by partings and running high in sulphur. In this respect there is not much choice between the two sets of coal, though the lower coals cover vastly the larger area and on the whole give promise of greater workability as regards thickness of benches. Until these coals have been explored west of their outcrop with the diamond or Calyx drill, they should not be entirely condemned. Their condition and quality in Ohio where they come to the surface on the west side of this basin, or in West Virginia, as well as their quality in other parts of Pennsylvania, indicate that they may prove well worth future investigation. For purposes of preliminary testing they can be reached most quickly at the axes of the anticlines across the larger drainage lines, and if the drill shows them there to be of workable thickness, and analyses of the cores show them to be of marketable quality, they can be followed on down into the synclines for purposes of development. Some workable coal is yet to be found in the Conemaugh formation, but for the present purpose it will suffice to review briefly the condition of the Allegheny coals along the western edge of this district, as exposed along Chestnut Ridge and the Ligonier Valley.

The Upper Freeport coal is the most valuable coal of the Allegheny formation in southwestern Pennsylvania. It is generally persistent and thick, reaching a maximum of 12 to 16 feet, but in these cases the coal is usually so broken up by partings that the minable part will seldom exceed 6 feet and is usually less. In most cases the largest single bench in the section runs from 2 to 3½ feet and often only one such bench will be taken under present mining conditions. The Lower Freeport coal is quite variable and usually thin. It may prove locally workable. Of the Kittanning coals, the Upper Kittanning appears to be the most important in this district. It shows a thickness of 5 to 7 feet on Cucumber run with 4 inches of clay parting 2 feet 3 inches from the top. On Smalleys run it shows 4 feet of coal in three benches through 11 feet 6 inches of space. Other sections show from 5 feet down of coal, usually rather badly broken up with partings. The Middle Kittanning reaches 4 feet in places usually including from 6 to 10 inches of clay. The Lower Kittanning appears to be unimportant.

In the space of the Clarion coal group there is a valuable coal 15 to 30 feet above the top of the Pottsville sandstone. It was formally mined along the Youghiogheny River near Ohiopyle where it is 2 feet to 4 feet thick. At Cool Spring Furnace, east of Uniontown, this bed is 8 feet 5 inches thick with 3 inches of clay 3 feet 3 inches from the top and 1 inch of clay 18 inches from the bottom. Few measurements of this coal have been made but numerous large blooms indicate that it may be workable over a considerable area. It is thought by J. J. Stevenson that this is the same as the valuable bed worked at Arden, Roaring Camp, and elsewhere in West Virginia.

The Mercer coal shows a thickness of 4 feet on the east side of Chestnut Ridge near the National pike. Uusually it appears to be thin, from a few inches to 2 feet.

BEAVER QUADRANGLE.

The rocks of this quadrangle include the Pittsburg coal and all the underlying coal measures. The quadrangle appears to contain extremely little of value from the coal standpoint. All of the beds except the Pittsburg have a workable thickness only locally and then barely reach workability.

About a dozen of the hilltops in the southeastern part of the quadrangle catch the Pittsburg coal. It is in too small areas and has too small cover to be of any commercial value in the quadrangle. None of the Conemaugh coals appear to be of workable thickness.

There remains all of the Allegheny coals which underlie practically the whole quadrangle. Of these the Upper Freeport is the most important. Where this coal is overlain by shale it may maintain a fairly uniform thickness, but where overlain by sandstone this thickness is liable to be variable, changing from several feet to a few inches or nothing within a few hundred feet. This coal will therefore everywhere require careful prospecting before development. In the northeast corner of the quadrangle this coal varies from 9 to 22 inches in thickness with an average of 17 inches. South of the Ohio river and east of Raccoon creek it runs from 1 or 2 inches to 35 inches of coal and partings. It is more irregular in the northern part of this area. Farther south it is about 26 inches thick and has long been worked for local use. North of Ohio river and west of Beaver river it averages 17 inches, running from 0 to 27 inches including coal and partings, though at the west are some irregular lenses of coal ranging between 30 and 56 inches. The coal in these places is usually pure and free from partings. South of the Ohio and west of Raccoon creek the coal is also lenticular but apparently in larger lenses. Locally the coal splits until the benches and partings occupy a space of 10 to 12 feet.

Sixty feet below the Upper Freeport is the Lower Freeport. It is commercially of little or no value. It ranges locally from 12 to 30 inches in thickness but elsewhere becomes merely bituminous shale with coaly streaks.

The Upper Kittanning coal seldom exceeds 6 to 8inches in thickness in this quadrangle except on Brush run where apparently this coal is about 4 feet thick with from 6 to 12 inches of parting.

The Middle Kittanning (Darlington) coal is from 4 to 36 inches thick, but on the whole is only locally of workable thickness even for neighborhood use.

The Lower Kittanning coal ranges up to 30 inches in thickness and in itself is of little or no value. It is, however, underlain by a valuable bed of clay and it is mined extensively in connection with the clay and for use in the burning of the clay. It is fairly regular not having been observed less than 14 inches nor more than 30 inches.

The Clarion coal is less than 12 inches thick and of no value.

The Brookville coal reaches 39 inches, mostly shaly, at the mouth of Brady Run, but otherwise it appears to be thin.

NEWCASTLE QUADRANGLE.

The coals of this quadrangle belong in the Lower Conemaugh, Allegheny, and Pottsville formations. Out of coals at fifteen horizons exposed in the quadrangle, three are known to be of value. These are the Upper Freeport, Middle Kittanning or Darlington, and Lower Kittanning. Three of the others are locally workable, the East Palestine (Mahoning coal?), Lower Freeport and Upper Kittanning.

The Upper Freeport is normally 4 to 5 feet thick separated by from 1 to 6 feet of shale from the overlying Mahoning sandstone and from 1 to 3 feet of clay from the underlying limestone. As elsewhere, however, the sandstone is liable to be found laid down on an old erosion surface which has cut into the coal, reducing its thickness or cutting it out. The area of this coal is not large in this quadrangle. As indicated on the map it is confined to the hills in the southern half, and due to the irregularities spoken of it is uncertain how much of the area is underlain by thick coal.

The Middle Kittanning coal (Darlington, "18-inch" or "3-foot") as a rule measures from 24 to 28 inches with a shale roof and clay floor. Partings are usually absent when the coal is thin, but where thickened one or more appear to be somewhat persistent. Though barely of workable thickness under present mining conditions, this bed appears to be so persistent that it may ultimately yield a large volume of coal. In the vicinity of Wampum many sections show 34 inches and up to 48 inches of coal.

The Lower Kittanning coal is but imperfectly known. As elsewhere it is here underlain by a thick body of valuable clay and its value will doubtless be mainly as mined in connection with the clay. It varies up to 36 inches in thickness though usually is much less than that. It is free from persistent partings though several sections show a tendency to develop a sulphurous clay parting 1 inch thick from 11 to 14 inches from the bottom. The area underlain by this bed is shown on the map.

On the scale of the map this line of outcrop will serve as well to show the area underlain by the Middle Kittanning coal. Of the other coals the East Palestine coal is opened along the western margin of the quadrangle Darlington township where it is known as the "3-foot" or "Red Hill" coal. It may prove to be workable in connection with the Upper Freeport which it overlies. It varies from 32 to 47 inches in thickness, including 8 inches of bony coal on top.

The Lower Freeport is rendered variable in thickness by an erosion that followed its laying down and which in turn was followed by a deposit of sand, so that while in general it appears to be from 10 to 19 inches thick, it varies from 6 to 48 inches, and it is barely possible that future prospecting will develop workable areas of workable thickness.

The Upper Kittanning here as elsewhere is notable for its association with cannel coal, while the bituminous coal is usually very thin. When thick the thickening is due to a deposit of cannel coal above the bituminous. This is best seen at Cannelton. Here the cannel coal has a thickness of up to 13 feet with an average of 7 to 8 feet. It fills a race-track-like trough about 300 feet wide extending around an oval 2 miles long by 1 mile wide. Bituminous coal is 1 foot thick in the center of this track-like basin but at the edges of the track the cannel coal thins out and the bituminous coal thins to 4 inches. This coal was formerly thought to be at the horizon of the Darlington coal, but later exploration exposed the Darlington below it in the hill and at the proper interval above the Lower Kittanning coal.

As shown by the distribution of the coals on the map, the northern part of the quadrangle has little of value in the way of coal resources. The coals outcropping there are mainly the Pottsville coals which in that region are usually not workable.

SEWICKLEY QUADRANGLE.

The Sewickley quadrangle includes rocks from the Pittsburg coal down. Excepting for a few hilltops in the south part of the quadrangle and one or two points on the northwest and west edges, all of the rocks of the quadrangle belong to the Conemaugh or lower barren Coal Measures. The Pittsburg coal is confined to the hilltops on the south edge of the quadrangle, most of these being south of Ohio river. Here it underlies areas of from 1 to 20 or 30 acres. All of these places have served for neighborhood use and in the main are all worked out. The coal has a total maximum thickness of 14 feet, of which about 6½ feet are taken. The lower division which alone is worked shows 3 feet of "breast" coal, 4 inches of "bearing-in" 2 feet 2 inches of "brick" coal, and 3½ inches of bottom slack coal. Partings run from 1½ to 2 inches. Of the Conemaugh coals, the Elk Lick has been opened south of Duff City, where it shows 30 inches of solid, clean, blocky coal underlain by 1 foot of dirty coal, 1 foot of yellow clay, and 1 foot of shaly coal. The coal here lies 20 to 40 feet above the Ames limestone and immediately under the Morgantown sandstone. On the Schley farm on the eastern border of the quadrangle, 3½ miles from the southeast corner, this bed shows 3 feet of good coal overlain by 40 inches of poor coal, shale and clay. Over most of the quadrangle this coal consists of from 0 to 12 inches of soft shaly coal of no value.

The Bakerstown coal has its maximum thickness in the northeast corner of the quadrangle near Lowville where it has been frequently opened and is still worked for neighborhood use. It shows 24 to 30 inches of coal with few or no shale partings. It is said to be low in sulphur and to burn with few clinkers. At other points throughout the quadrangle where opened it has been found to be thin and of poor quality.

The Gallitzin or Brush creek coal reaches its maximum thickness in its type locality on Brush creek near Oak Hill in the north central part of the quadrangle. It is here 24 to 32 inches thick and of fair quality. It has been mined here in a small way, but not within recent years.

Where exposed along the northwestern and northern edge of the quadrangle the Allegheny coals have been mined in a small way but most of these mines are now abandoned. The Allegheny coals underlie practically the whole quadrangle, but little can be told of the thickness and quality until prospecting by drill has been done. Upon them depends the future output of coal from this part of the quadrangle.

CLARION QUADRANGLE.

The outcropping rocks of the Clarion quadrangle are almost entirely of Allegheny age. The Upper Freeport coal bed underlies the hilltops throughout the southern part of the quadrangle. With the exception of a few isolated hilltops in which country banks have been opened, the only commercial development of this or the Lower Freeport coal which lies about 40 feet lower, has been in the vicinity of New Bethlehem. The Freeport coals are of excellent quality and of good thickness but are of comparatively small extent and have been largely worked out. On a hilltop 1½ miles south of Rimersburg is an old opening on a coal 4 feet 4 inches thick which has been supposed to be of Upper Freeport age, but of which the evidence favors belonging to the Mahoning horizon. As a rule the roof of the Upper Freeport is sandstone and of the Lower Freeport shale. A section of the Upper Freeport 2 miles south of Sligo shows 3 feet 3 inches of coal overlain by 7 inches of bony coal. The section of the Lower Freeport in Mine No. 11 of the Fairmount Coal Company, 3 miles north of New Bethlehem, shows a total of 4 feet 2½ inches, with ½ inch sulphur parting 2 feet 2½ inches from the top, and a similar parting 10 inches from the bottom. The Kittanning group of coals as described under Stratigraphy consists of four or five beds to which may be applied the names Upper Kittanning, Gorman, Middle Kittanning, Darlington and Lower Kittanning, with a small bed below the Lower Kittanning which may or may not be a split of that bed. The uppermost coal, designated the Upper Kittanning in the general section, is fairly persistent and where opened averages 2½ feet in thickness, except in the vicinity of New Bethlehem where two sections of 3 to 4 feet were measured, In the latter case there are several bony benches which largely destroy the value of the coal. The coals between the Upper Kittanning and Lower Kittanning have been seldom opened and on account of their proximity have been traced with some difficulty. It is only in a few places that all of them seem to outcrop in a single section.

The Lower Kittanning coal is the most important of the quadrangle. It is persistent, uniform in thickness and widely distributed. Its horizontal position is indicated on the accompanying map by its line of outcrop. The average thickness of sixty-six sections is 3 feet. Of the total number of measurements, nine were under 2½ feet and 8 over 3½ feet. No regular partings occur in the coal and the irregular ones are thin, few of them being over ½ inch in thickness. In about one-half of the sections measured no partings were noted. From 6 to 12 inches below the top of the coal, however, occurs a binder of splinty character from ½ to 2½ inches thick, which is readily distinguished on fresh faces of the coal and which is probably persistent nearly everywhere. No attention is paid to this binder in mining. At many places the upper portion of the bed consists of 2 to 12 inches of bony coal, thus making the average thickness of clean coal 1 to 2 inches less than 3 feet. In all of the openings examined the roof is shale and the floor clay. It was reported that this coal was coked for use in some of the old natural draft iron furnaces which formerly existed in Clarion county, but a recent attempt to coke it in some experimental ovens near Rimersburg is reported to have been unsuccessful. The analyses show that the coal is high in sulphur and moderately high in ash. At a distance of from 5 to 15 feet below the Lower Kittanning occurs a bed which is developed only in the northern half of the quadrangle. This is either a split from the Lower Kittanning or a separate bed. The fact that the Lower Kittanning is seldom if ever appreciably reduced in thickness favors the hypothesis that there are two beds. This coal is usually less than 2 feet thick, so that it is hardly a mining proposition, though it has been opened in a few places. The Clarion coals in the southern half of the quadrangle are of little or no commercial importance. Openings south of Mayport and 3 miles west of New Bethlehem show 26 and 27 inches of coal respectively. In the northern half of the quadrangle the coal is much thicker, the average of four sections on one of the coals being 3½ feet. The Clarion coal in this region lies immediately below the pinkish massive sandstone which makes many flats and benches in the vicinity of Clarion river and is locally known as the "sulphur" vein.

The Brookville coal lies usually about 90 feet below the Lower Kittanning. The few sections indicate that it is thin and dirty over most of the quadrangle. At Sligo, however, there are two commercial mines on this coal in which the bed shows a thickness of about 3 feet and although high in sulphur has a ready sale for steam purposes. The extent of coal having this thickness and quality is at present not definitely known. It developed however 3 feet at one point northeast of New Bethlehem but with two sulphur partings.

KITTANNING QUADRANGLE.

The coals of the quadrangle are those belonging in the Allegheny formation. The coal lies low in the hills at the south edge of the quadrangle, the lowest coals being below drainage. The general northward rise carries the coals higher in the hills, until at the north edge of the quadrangle the uppermost coal, the Upper Freeport, occurs high in the hills, and near the river is caught only by the higher hilltops. The underlying coals outcrop in the hills in the space of 300 feet. The Lower Kittanning coal reaches the level of flood plain of Allegheny river at Kittanning. The rise from the south to the north is not steady, but much affected by the structure.

The Upper Freeport coal is next to the Lower Kittanning the most valuable coal in the quadrangle. It is worked commercially only at Karns. It was formerly extensively mined near East Brady, and over a considerable area southeast of Kittanning. At Karns it is a solid coal 51 inches thick. Above the railroad tunnel on Long Run it is 50 inches, and one-half mile east of Fenelton it is 45 inches, overlain by 9 inches of coaly shale. It is 50 inches thick at Brady's Bend, with a 3-inch shale parting and small benches of coal above and below. One mile west of Sherratt it is 45 inches thick, with 2 inches of shale 18 inches from the bottom. Two miles northeast of Kittanning it is 48 inches thick, with 2 inches of bone 10 inches from the bottom. Over the quadrangle in general it will range from 2 feet to 3 feet or more. In many places the upper part of the coal is shaly, and in some cases almost or quite all of the coal is shaly.

The Lower Freeport coal, as far as known, is workable only in comparatively small areas. The largest of these extends along Glade run on the south border of East Franklin township to Cowansville, and thence possibly through the hilltops to Peach Hill. It is about 5 feet thick in the tunnel 1 mile southwest of Cowansville, and 4 feet in a cut midway from Cowansville to Adrian. It was formerly mined near Kittanning, and it is probably workable over considerable areas in South Donegal and North Clearfield townships. It is mined commercially only at Cowansville.

The Upper Kittanning coal is usually a mere streak only a few inches thick, but locally swells out to a workable thickness. At Summerville it shows 2 feet of bituminous coal at the outcrop, but thickens rapidly to 5 feet in the mine. The coal is underlain by a bed of cannel shale of no value, which thickens until 7 feet thick, making 12 feet for the bed as a whole. It has been mined at Kayler, 1½ miles northeast of Marrows Corner near Sherratt and Adrian, and on to the Allegheny river near Cowansville and on Long Run. It appears to be very irregular, and is known as the "Pot" vein.

The Middle Kittanning coal is nearly 5 feet thick one mile south of Wattersonville, and it shows a thickness of 15 inches north of Applewold. Otherwise little is known of it.

The Lower Kittanning coal is the most persistent and valuable bed of the quadrangle. It is of minable thickness wherever found. From its low position in the hills it underlies nearly the whole quadrangle.

It is rarely less than 2½ feet thick, and generally runs nearer 3½, even reaching 4 feet occasionally. It is often much broken up by shale partings, which impair its purity, and it is sulphury in places. It is mined commercially at River View or Cosmos, at the Monarch mines north of the Allegheny river 1 mile above the mouth of Red Bank creek, and on the south side of the Allegheny river below Philipsburg. In 1903 large operations near Kayler were in prospect. It is used at Kittanning in the manufacture of brick.

In the Clarion group are two coals. The upper bed is from 15 to 20 feet below the Vanport limestone. It is 3 feet 8 inches thick at West Greenfield. It is 2 feet thick northwest of Craigsville, but in general does not appear to be a coal of any value. Forty to 50 feet below the Vanport, and 25 feet below the coal just described is a coal locally known as the Craigsville. It is 3 feet thick 2 miles northwest of Craigsville. This bed was seen at many points west of Craigsville, but not generally through the quadrangle.

The Brookville coal is reported 3 feet 2 inches thick opposite the mouth of Long run in West Franklin township, but worthless. In general it appears to be of little value.

RURAL VALLEY QUADRANGLE.

The coals in this quadrangle belong in the Allegheny formation. They are below drainage in the southeast corner, and the Upper Freeport is above the hilltops in the northwest corner. In general, however, the coals occupy the lower slopes of the hills and underlie most of the quadrangle. This is especially true of the lower coals.

The Brush creek coal has a thickness of 20 inches to 2½ feet locally, and has been mined on a small scale. It is probably not workable over much of the quadrangle.

The Upper Freeport coal is by far the most valuable coal in the quadrangle, although its area is less than that of any other. The coal is reported to be excellent for steaming or heating, but is too sulphury for gas making or coke. It is locally affected by "rock faults" or "rolls." These are sometimes true sandstone horsebacks. In other places coal and shale replace each other within short distances. At New Bethlehem the coal is 4 feet thick without partings. At the Red Bank mine it is the same thickness, but has 6 inches of bone on top. At the Oak Ridge mine it is 3 feet 5 inches. Over the rest of the quadrangle it shows great uniformity, ranging from 3 feet to 6 feet 6 inches, sometimes solid, but often with thin partings, and at the Yatesborough mines showing two partings at the top. Thus north of Deanville it is 52 inches; one mile east of Templeton it is 35 inches; east of Goheenville 44 inches; near McCrea Furnace 47 inches; southwest of Putneyville 46 inches; east of Charleston 47 inches; northeast of Muff 52 inches; 1½ miles west of Dayton 48 inches; southeast of Echo 49 inches; at Mosgrove 42 inches; at Cowanshannock creek 62 inches; east of McNees 44 inches; west of Blanket Hill 25 inches; Yatesborough mines from 32 inches to 42 inches of minable coal; at Blanco 48 inches of coal; at Garrett run 78 inches; east of Heilman 47 inches. This coal is mined commercially at Yatesborough, Mosgrove and near North Bethlehem. The Lower Freeport coal is more variable than the Upper Freeport. It is generally a bright, clean coal, and where workable varies from 2 to 4 feet. It lies 35 to 60 feet below the Upper Freeport. It has been worked around New Bethlehem, where it is 3½ to 4 feet and up to 6 feet thick, but badly cut up by clay veins. It is reported 5 feet thick 1½ miles northwest of Goheenville. Around Echo and Oscar it is from 2 to 2½ feet thick. On Cowanshannock creek it is very pure and of fair thickness, ranging about 30 inches. This coal is worked commercially only in the northeast corner of the quadrangle.

The Upper Kittanning coal is an important coal in the northeast corner of the quadrangle. Its general thickness varies from a few inches to 3 feet, but in local basins of small extent it is 10 to 15 feet thick. In these basins the bed consists of one or two benches of cannel and of bituminous coal. Thus at the Bostonia mine the bed shows 8 feet of cannel over 2 feet of bituminous coal. As usual the cannel coal occurs in narrow basins, holding its thickness along the main entry, but pinching out either side. Near Putneyville this coal shows 5 feet of cannel shale, 1 foot of bituminous coal, 7 feet of connel coal, 2 feet of bituminous coal, a total of 15 feet. It is also thick on the east side of Muddy and east of Charleston. While this so-called cannel has all the appearance of cannel, analyses would indicate that it was chemically a high ash bituminous coal, as it shows from 30 to 37 per cent. of volatile, and 46 to 53 per cent. of fixed carbon, and 6 to 2 per cent. of ash. On Pine creek this coal is fairly persistent, and of moderate thickness,—from 2 to 5 feet. It was once mined extensively for coke near Pine Furnace. It is 2 feet 8 inches thick near Echo, and from 18 inches to 3 feet on Cowanshannock creek. Outside of the areas mentioned it does not give promise of yielding more than 1½ to 2 feet of coal.

The Middle Kittanning coal is not an important bed in this quadrangle, though it reaches 3 feet or better in some places. Near Mahoning Furnace it is 3 feet or less thick. Above Echo it is 2 to 3 feet, and is reported 5 feet. In general it is probably 18 inches or less in thickness.

The Lower Kittanning coal is one of the most important coals of the quadrangle. It is thickest in the part of the quadrangle west of the line drawn roughly from Kellersburg to Kittanning. Over a limited area near New Bethlehem and along Mahoning creek from Putneyville eastward and south of Mahoning creek to near Belknap, the coal shows a thickness of from 2 to 4 feet, with an average where workable of about 3 feet. It has usually no thick partings, though sometimes broken up with thin partings, and occasionally shows bone on top. It lies low in the hills, so that it underlies nearly all of the quadrangle. In the southeast corner of Mahoning township this coal appears to be split into three benches included in an interval of 34 feet. It is possible the upper bench represents the Darlington coal of farther west, and the bottom bench the coal below "B" in the Clarion quadrangle.

The Clarion coals do not appear to be of workable thickness in this quadrangle.

The Brookville coal appears to be of workable thickness only along the upper portion of Mahoning creek. It varies in thickness from 2 to 4 feet in two benches separated near the middle by a parting 2 to 8 inches thick. It is hard, lustrous and splinty. Outside of that area, while generally present, the indications are that it is thin and worthless.

ELDERS RIDGE QUADRANGLE.

The Elders Ridge syncline in this quadrangle carries the rocks down so that about 14 square miles of the Pittsburg bed have been preserved. Nearly the whole quadrangle is underlain by Allegheny coals which are exposed in the valleys or brought up with the structure.

The Pittsburg coal occupies an irregular basin in the south central part of the quadrangle. It is divided into three large blocks and several smaller ones by Whiskey run, Big run and other streams. The Jacksonville anticline brings up the Upper Allegheny coals about Jacksonville and about Altmans and Reeds runs and their tributaries in the southeastern corner of the quadrangle. On the northwestern half of the quadrangle the structure is high and the Allegheny coals outcrop along the valley of Crooked run and its tributaries and on Roaring creek. The Dutch run anticline brings up an area of Upper Freeport coal on Dutch Run.

The Sewickley coal shows an outcrop near the center of the Elders Ridge Syncline. Exposures do not indicate a thickness of more than 2 feet though it is reported to have shown over 5 feet near Elders Ridge, but it is much broken up with partings.

The Pittsburg coal in this quadrangle occupies a basin 9 miles long by 3½ miles wide with an average thickness of 7 feet. In parts of this basin this coal is clean and almost without partings; in other places it is shaly and has many partings. Including the roof coal it sometimes reaches a thickness of 10 feet. Generally, as elsewhere, the roof coal is not taken on account of the thin beds of hard shale it contains and the tender character of the shales over it. The best sections of the coal show nearly 7 to 9 feet of coal with one parting of not more than 1 to 6 inches of shale. The poorer sections may show the bed broken up into three or four benches with partings that would aggregate 1½ feet of shale.

The Upper Freeport or "4-foot" bed as it has been called, has a long line of outcrop especially in the drainage of Crooked creek. It will average a little under 4 feet in thickness, the extremes being 27 inches and 55 inches. The coal is everywhere shaly and high in sulphur. On Coal run and Altmans run it will range from 3 feet 6 inches to 4 feet 7 inches, and average 4 feet. The sections show 3 inches of bone and shale 6 inches from the bottom. On Roaring run it is persistently 4 feet thick wih a 1 inch parting. One mile west of Long run this bed shows a thickness of 7 feet 2 inches including 15 inches of parting 3 feet 8 inches from the bottom. On Plum creek in the northeastern quarter of the quadrangle the coal measures 2 feet 10 inches to 3 feet 6 inches. In the northwestern part of the quadrangle the coal ranges from 3½ to 4½ feet, thinning locally to 27 inches.

The Lower Freeport on Neal run near Jacksonville reaches a thickness of 5 feet 2 inches. At most points where seen it will not measure more than 2 feet in thickness. The coal is firm, mining out in large blocks resembling a block coal not only in that way but in the dull layers and bands of mother-of-coal. Analysis shows a good steam coal, and though a little high in ash and sulphur, it is a good coking coals.

The Upper Kittanning coal is 2 feet thick on Crooked creek but elsewhere it decreases to a mere streak. The Lower Kittanning is below water level on Crooked creek. Below South Bend it shows a thickness of 2½ to 3 feet but the sections show the coal so badly broken up with dirt bands as to be nearly or quite worthless.

LATROBE QUADRANGLE.

The Latrobe quadrangle contains all of the coal measures from the bottom of the Dunkard down. The Waynesburg coal occupies a couple of hilltops between Klondike and Hostetter in the Latrobe syncline. The Pittsburg coal occupies a narrow belt across the southeast half of the quadrangle following the Latrobe syncline. The Greensburg syncline brings in another small area extending part way across the quadrangle and in the northwest corner the Elders Ridge syncline is responsible for a small volume of Pittsburg coal under the hilltops.

The Allegheny coals are brought to outcrop in the southwest part of the quadrangle by the Chestnut Ridge anticline and they underlie practically all the rest of the quadrangle.

The Waynesburg coal, as stated, occupies only a very limited area where it shows a section of 4 feet. It is shaly throughout and of little value, and as the same is true of the other beds above the Pittsburg in this area, they may be omitted from any estimate of the coal resources of the quadrangle.

The Pittsburg coal shows somewhat the same typical section as in the main field to the southwest. The roof coal is sometimes lacking but is generally present with a thickness of from 6 inches or less up to 4 feet. It is usually broken up so as to be worthless. The main clay runs from 4 inches to 1 foot 9 inches, usually being a little over 1 foot. The lower division runs from 7 feet to over 8 feet in thickness; the "bearing-in" is from 3 to 10 inches thick; the "breast" coal from 4 to 5 feet thick, the top few inches often being bony; the "bottom" coal, including the "brick" coal is from 2 feet to 3 feet 6 inches. Of this the "brick" coal usually runs from 6 inches to 1 foot. The coal from near Blairsville yielded (McCreath) the following analysis:

Moisture,	1.85
Volatile matter,	27.38
Fixed carbon,	49.84
Sulphur,	3.01
Ash,	19.01

In the Conemaugh formation the Gallitzin coal shows a thickness of 2 feet just off the south margin of the quadrangle. The coal which appears to be either the Elk Lick or Bakerstown along Dry Ridge west of Latrobe has at one place a thickness of 3 feet 9 inches.

The Upper Freeport coal is decidedly the most important of the Allegheny coals in this quadrangle. It has been extensively prospected and worked along both sides of Chestnut Ridge and at many points on the crest. The coal shows a thickness of from 4 feet to over 8 feet. Uusually it has clay or shale partings of from 1 inch to 2 feet, though averaging but a few inches. The coal appears to be low in ash but high in sulphur,—over 2. Notwithstanding this it seems destined to become an important source of coal after the exhaustion of the Pittsburg bed.

The Lower Freeport has been but little prospected and not much is known of it. It is 4 feet 10 inches on Elders Ridge including 8 to 12 inches of shale, and is reported 3 feet thick on Loyalhanna creek.

The Kittanning group of coals has been prospected but little and while detached openings, outcrops and drillings indicate the general presence of beds from 2 to 6 feet thick in this position, the data are too meagre to correlate so as to arrive at any general conclusion in regard to their value. Apparently the Upper Kittanning is the most persistent and valuable of the group in this region.

The coals of the Clarion group are poorly exposed and seldom seen. Apparently they are not of workable thickness.

INDIANA QUADRANGLE.

The Conemaugh and Allegheny coals outcrop in this quadrangle. The Allegheny coals underlie nearly the whole quadrangle. They are exposed along Chestnut Ridge and in some of the valleys they are brought up by the anticlines. The coals in the Conemaugh usually measure only a few inches.

The Mahoning coal, 60 feet above the Upper Freeport, reaches a barely workable thickness of 2 feet on Lower Pine Run. And near Gaibleton the Gallitzin coal reaches a reported thickness of 3 feet on the headwaters of Crooked creek and toward Two Lick creek. It is from 100 to 130 feet above the Upper Freeport.

The Upper Freeport cool is much the most imoprtant of the Allegheny coals. While locally absent or thin it reaches a thickness of 5 to 7 feet over considerable areas, and is the cause of some of the most extensive mining plants in the State. As a rule this coal is in two benches, of which the lower is the thicker, separated by 4 to 10 inches of shale. At Graceton the upper bench is 2 feet 6 inches and the lower 3 feet 6 inches thick, separated by 8 inches of shale; on Tearing run the two benches are respectively 1 foot 7 inches and 3 feet 9 inches thick, with 8 inches of shale parting. At the Gable mine the parting is bone, 8 inches. The benches are 1 foot 2 inches and 3 feet 5 inches. On Two Lick creek the benches are 2 feet 3 inches and 4 feet 2 inches with 10 inches of shale between. Near Greenville there are two partings, the upper 3 to 6 inches coming to 8 to 9 inches from the top, and the lower 1 to 3 inches thick coming 8 to 10 inches from the bottom. The middle bench of the coal is about 2 feet thick. Opposite Chambersville the benches are 1 foot 6 inches and 3 feet with 6 inches of shale between. On McKees run they are 1 foot 6 inches and 3 feet 8 inches with 6 to 12 inches of shale between.

The Lower Freeport coal does not appear to be persistent or thick in this quadrangle. As far as known it is minable only in the northeast part of the quadrangle near Dixon and Rayne runs. The coal in that district varies from 3 feet 6 inches to 4 feet 4 inches.

The Kittanning coal group is in general represented in this quadrangle only by the Lower Kittanning. Thin coals in the drillings indicate the presence of other coals here and there. The Lower

Kittanning underlies practically all of the quadrangle. Where measurements are possible the coal shows a thickness of from 3½ to 7 feet. Like the Upper Freeport it is usually in two benches separated by about 1 foot of shale. In this case the upper bench is the thicker. For example, on Ramsey run it shows:

Coal,	3 feet 8 inches.
Shale,	1 foot 4 inches.
Coal,	1 foot 2 inches.

At Lydicks on Allen run it shows:

Coal,	3 feet 6 inches.
Shale,	1 foot
Coal,	2 feet 6 inches.

As far as known the other coals of the Allegheny are not workable.

JOHNSTOWN QUADRANGLE.

The coals of this quadrangle are those of the Allegheny formation. Six coals are locally workable, but not more than four, and usually not more than two or three, are persistently valuable. The uppermost of these is the Upper Freeport or "E" coal (the "coke yard" coal about Johnstown and the "Lemon" coal at South Fork). This coal is used for domestic and steam purposes, but expands in coking so as to not serve well for that use. It is high in ash and sulphur. Forty-five to 70 feet below is the Lower Freeport or "D" coal ("limestone bed"), which at present is little mined in this quadrangle. Eighty to 105 feet below the Upper Freeport is the Upper Kittanning or "C" coal ("cement bed"), which is one of the most persistent and valuable beds in the quadrangle. It makes a good steam coal and is successfully coked. The Middle Kittanning is usually not workable here. From 180 to 200 feet below the Upper Freeport is the Lower Kittanning ("Miller," "white ash," or "B" bed), which is the most persistent and valuable bed in the area. It is a high grade steam coal, one of the best in the State and is successfully coked after washing with fairly good results. Sixty-five feet below the Miller bed is the Brookville coal, with the Clarion coal a short distance above.

Johnstown District. The "E," "D," "C" and "B" coals are workable about Johnstown. The "E" coal shows a thickness of 3 to 3½ feet, with a lower bench below, 1 to 6 inches thick, separated from the main bench by 1 to 6 inches of bone and shale. The "D" coal is not worked at present in this district. Along Stony creek it showed: Coal, 12 inches; parting, 1 inch; coal, 22 inches; parting, 1 inch;

coal, 4 inches. The roof is bone and black shale, with sandy shale or sandstone. See B, plate XI. The Upper Kittanning or "C" coal lies at a convenient height above drainage for exploitation about Johnstown, where it is the bed most largely exploited. It has a thickness of from 3 to 5 feet, with a shale and sandstone roof and a floor of shale or limestone. It averages between 3 and 3½ feet thick, but thickens to 5 feet along Stony creek toward Windber. See A, Plate XI. The Lower Kittanning coal is below drainage just at Johnstown, where it is worked by slopes or shafts. It rises above drainage east, west and south of the city. It shows a main bench of about 3½ feet of coal, with often a lower bench of up to 14 inches, below a parting of 6 to 14 inches. It has a good roof of shale or sandstone and an irregular floor of shale or clay. The under clay is mined at many of the mines.

South Fork District. The Allegheny coals rises above drainage just east of Ehrenfeld and at South Fork. The "E" coal consists of two benches or of three, of which only the two lower are workable. The Upper bench is from 1 to 2 feet thick, and the lower from 1½ to 2 feet. The bone or shale parting is from ½ to 2 inches thick, and is very persistent. The Upper Kittanning coal is from 3 to 3½ feet thick, with the cement limestone appearing 8 or 9 inches below. The Lower Kittanning coal 160 feet below the Upper Freeport is the most extensively worked coal in the district. It shows a main bench 3½ to 4½ feet thick, with a lower bench 2 to 36 inches thick below a parting of 1 to 15 inches. The roof and floor are as in the Johnstown District. The Brookville coal shows a thickness of 3 feet 6 inches near South Fork.

Black Lick District. All the coals rise above drainage from Vintondale eastward to Nant-y-Glo. Mining at Wehrum is by shaft. The "E" coal is from 3 to 3½ feet thick in two benches separated by the small bony parting 1 to 3 inches thick, with a bony floor. The Middle Kittanning shows 33 inches near Twin Rocks. The Lower Kittanning is the main bed of the district. Its section here is similar to its section in the other districts: A main bench 3½ to 4 feet thick, with one or two thin and irregular benches below.

Windber District. This district just overlaps the south edge of the quadrangle. The Allegheny coals are above drainage, but only one, the Lower Kittanning, is worked. The Upper Kittanning coal shows a clean face 4½ to 6 feet in thickness under a firm shale roof. North of Windber the Upper and Lower Freeport coals above this have been little prospected. The Lower Kittanning here is a very high grade coal with low ash and sulphur. It is about 3½ feet thick, not including a lower bench 3 to 8 inches thick lying 3 to 24 inches below the worked bench. It lies low in the hills, so that it is mined by drifts.

EBENSBURG QUADRANGLE.

There are eleven coal horizons in the Ebensburg quadrangle including what may be the Pittsburg coal in the Wilmore basin, the Gallitzin coal in the Conemaugh, the "E," "D," "C^1," "C," "B^1," "B," "A^1" and "A" in the Allegheny, and the Mercer coal in the Pottsville formation.

The Allegheny coals underlie practically all of the northwest half of the quadrangle, the outcrop of the formation forming a nearly straight line from the northeast corner to the southwest corner.

The so-called Pittsburg coal occurs only in the high hill south of Wilmore where it has a thickness of 2 feet 8 inches including 4 inches of shale. The Gallitzin coal has a thickness of only 15 inches or under.

The Upper Freeport (E or Lemon seam) is everywhere a workable and valuable bed along its outcrop. It is elsewhere characterized by a hard parting 12 to 18 inches from the bottom. The coal runs from 2 feet to 5 feet in thickness, most of the section showing over 4 feet. The parting is shale sometimes with bone or coal from 3 to 6 inches thick. The coal has a fuel ratio of from 2.5 to 3.5 or over. The fixed carbon runs from 64 to 74 per cent., the volatile matter from 17 to 20 per cent., the ash from 5 to 8 per cent., the sulphur from .94 to 3.34 per cent., and the moisture from .71 to 1.41.

The Lower Freeport coal appears to be generally under 2 feet thick though reaching 3 feet 6 inches in a drilling south of Llanfair.

The Upper Kittanning is locally workable having a thickness on Trout run of 7 feet 2 inches, of which 3 feet 7 inches is in one bench. In the Bennington shaft it is 2 feet 10 inches; in the Sonman shaft 2 feet; in the Yellow Run shaft 2 feet 6 inches. It does not, however, appear to be generally workable.

The Middle Kittanning is rarely of workable thickness. In the Bennington shaft it shows 2 feet 8 inches, including 6 inches of clay 6 inches from the top.

The Lower Kittanning, as far as known, is a workable bed throughout its outcrop across the quadrangle and is very uniform in thickness and character; it averages 3½ feet mostly clean coal. Locally there is a layer of bone at the top which may reach a thickness of 1 foot. At other points the parting, of shale, occurs in the middle of the bed. The coal is relatively soft, very lustrous, and like most coals close to the Allegheny front, it is long-grained, cleaving into long prismatic columns. It has about the same composition as the Upper Freeport, already given. It is largely used as a steamboat fuel, going to the Atlantic for that trade, or even to Alaska.

Less than 20 feet above the "B" coal is a persistent bed of coal that on Bens creek reaches a thickness of 3 feet 7 inches to 4 feet, including 3½ inches of clay 5½ inches from the bottom. The clay is usually thin,—1 foot or less, though reported 3 feet 10 inches in the Sonman shaft.

The Brookville is locally of considerable thickness. At Bennington it is 4 feet thick but somewhat broken up. Over the quadrangle in general it appears to be worthless.

The Mercer coal of the Pottsville appears to be of workable thickness locally, as at the Eleanor mine above Martindale.

The coals of the quadrangle are known only along the eastern margin of the Wilmore basin. Their character in the center of the basin is conjectural, yet as they appear to have much the same character on the western side of the basin at South Fork, there is good reason for believing that they preserve their character and thickness under much or all of the basin.

BARNESBORO AND PATTON QUADRANGLES.

The rocks of these two quadrangles include probably all of the Conemaugh and the underlying rocks. The coals of value belong in the Allegheny formation.

Upper Freeport Coal. This is not extensively developed except near Barnesboro. It has a columnar structure, is rather hard, shows a bright fracture, and is generally free from sulphur and iron nodules. In the areas where it is being worked it is from 39 to 44 inches thick, not including the bottom bench of 4 to 6 inches separated by 8 inches of shale and bone from the coal above. It also frequently has a binder near the top. Outside of the areas of development it may vary from 0 to 4 feet, as indicated by drillings and outcrops. It shows by a recent analysis:

Fixed carbon,	62	per cent.
Valatile hydrocarbons,	25	per cent.
Ash,	12	per cent.
Sulphur,	.28	per cent.
Moisture,	.7	per cent.

Lower Freeport Coal. This bed is the most widely known and extensively developed bed in the field. The characteristic feature is a very persistent binder 8 to 12 inches from the bottom. Over 40 commercial mines are worked on this bed in this area. In these mines the coal averages 47½ inches,—practically 4 feet. It ranges from 37½ inches to 61 inches. There is sometimes a little bone on top of the coal. Clay veins are a great source of trouble in this bed, sometimes rendering its mining unprofitable. The majority are not over 14 to 20 inches thick. Scarcely a mine is free of them. Some roof rolls are met with. The Lower Freeport coal carries a large amount of sulphur in the form of "knife blades" and iron nodules in many parts of the region. Impurities seem to decrease west of Barnesboro where the coal becomes suitable for coking. Coal from the Greenwich mines near Garman's Mill is successfully worked, analysis showing:

Fixed carbon,	66	per cent.
Volatile matter,	25	per cent.
Ash,	7.75	per cent.
Sulphur,	.84	per cent.
Phosphorus,	.004	per cent.
Moisture,	1	per cent.

Upper Kittanning Coal. Fifty to 90 feet below the Lower Freeport is the Upper Kittanning coal which has been developed only around Hastings and Patton. Around Patton it shows 4 feet or more of coal including 2 feet of dirty coal not mined. "Knife edges" of sulphur are abundant, but the bed is free from clay veins and rolls. Under the coal is a fine bed of clay 6 feet thick. On the whole this bed is probably quite thin and not workable. Analysis shows an even higher percentage of fixed carbon than the Upper Freeport, as follows:

Fixed carbon,	67.05	per cent.
Volatile matter,	23.7	per cent.
Ash,	7.8	per cent.
Sulphur,	1.38	per cent.
Moisture,	.91	per cent.

Lower Kittanning Coal. This bed is here from 130 to 175 feet below the Upper Freeport. Drilling has shown this bed present and probably workable throughout the entire area, but it has only a limited outcrop. It is usually quite badly broken up with partings. Here the mines show a thickness of 38 inches on the average, not including two underlying benches which contain together nearly 2 feet of coal. This coal is of very high grade here. An analysis showed:

Fixed carbon,	70.9	per cent.
Volatile matter,	23.2	per cent.
Ash,	5.4	per cent.
Sulphur,	1.12	per cent.
Moisture,	.43	per cent.

As a rule the coals in these quadrangles are rather deeply buried. They come to outcrop mainly where the anticlines cross the major drainage lines. Thus the Chestnut Ridge anticline brings the upper coals above Two Lick creek and its north branch in the neighborhood of Mitchell's Mills and Pleasant Valley. The Nebo anticline brings the same coals up on Yellow creek and the west bank of the Susquehanna near Garman's Mills, from where they continue above drainage upstream to El Mora. The Laurel Hill anticline is responsible for small exposures of the Allegheny rocks and coals in the southeast corner of the Barnesboro quadrangle and along Chest creek below Patton. A general rise to the northeast brings these coals above drainage all along the north edge of the Patton quadrangle, and the rise to the Allegheny Front leaves the whole of the Allegheny formation above the level of Clearfield creek in the southeast part of the Patton quadrangle. The bulk of the coals in these quadrangles, however, will have to be reached by shafting. All of the coals here are irregular and it will be necessary to determine with the drill, in most areas, how many and what coals underlie and are minable.

PUNXSUTAWNEY QUADRANGLE.

The coals occurring in the Punxsutawney quadrangle all belong in the Allegheny formation. Some 400 feet of the Conemaugh formation remain, but the contained coals nowhere appear to be workable. The Upper Freeport, or "E" coal, as it is locally called, the Lower Freeport, or "D" coal, the Lower Kittanning, or "B" coal, and the Brookville, or "A" coal, are being mined commercially, and the Upper Kittanning is locally workable. Of the coals mentioned, the Upper Freeport is the coal being mined at Rossiter, the principal coal in the Glen Campbell district, and the coal being worked on the ridge north of Newtonburg. The Lower Freeport is the coal being mined all through the Punxsutawney-Reynoldsville field, and to some extent around Glen Campbell. The Lower Kittanning is mined on Horton run, near Glen Campbell, and the Brookville coal is mined commercially at several points in the Bear run basin, at Sidney and near McGees.

In the portion of the Punxsutawney basin north and west of Mahoning creek practically all mining at present is on the "D," or Lower Freeport coal. This bed ranges from 4 to 6 feet in thickness, running up to 10 or 11 feet locally. Around Adrian, Walston and Elk run it will average about 5 feet 6 inches. Toward Big run and Eleanora it is thin, ranging from 4 to 4½ feet. It is practically a solid coal, though often carrying a bony of 8 inches or less on top. At Eleanora shaft, where the coal runs from 6 to 9 feet in thickness, there is a strong band of bone in the center. The roof is of shale, generally showing a thickness of 12 to 14 feet or more, but in places this is thin and overlain with a sandstone that comes down close to or lies directly on the coal. Indeed, where Punxsutawney lies, and to the northeast over a broad, but irregular, belt the sandstone fills an old channel in which the coal was removed soon after its deposition. See B, plate XI. A number of entries have been driven through this, showing a width of 400 to 1,000 feet or more. The coal is a high grade coking coal and is very extensively coked at Walston and Adrian. In this portion of the quadrangle the "D" coal is mainly below drainage. It lies at about 1,050 feet above tide, in the center of the synclinal axis from Punxsutawney to Eleanora shaft. To the northwest it rises rapidly until in the northwest corner of the quadrangle it is found only in the hilltops, at an elevation of 1,650 feet.

From 38 to 43 feet over the Lower Freeport is found the Upper Freeport, or "E" coal. It is extremely irregular in this district, frequently reaching 4 feet, but is thin, showing only a few inches, and often it appears to be entirely gone. The evidence points towards its having suffered from erosion just after its deposition, in much the same way as the "D" coal. On account of these facts and the fact that it will have been undermined, it possesses very little value in this district. Little is known of the coals below the "D" coal, but it is claimed that they are worthless.

Northwest of Canoe creek and south of Mahoning creek, is a district that appears to be almost devoid of coals. Drillings strike practically no coal until to a depth that should reach at least to the "B," or Lower Kittanning, coal, which is thin.

In the district drained by Canoe creek to Ugly run, the "E," or Upper Freeport, coal appears to be free from the erosional action just described, and in this territory from Locust to Winslow, past Rossiter, it is uniformly workable, with a thickness of from 3 to 5 feet. Within this area the Lower Mahoning section is occupied almost entirely by shale. The coal is usually without partings, though occasional partings appear near the bottom, and bony coal from 4 to 10 inches thick is frequently found at the top or bottom, and occasionally at both. The roof is always shale. To the north and northeast of Winslow the coal is less regular, frequently thinning from 4 feet to 8 inches in a few hundred feet. In this district the Lower Freeport is thin and hardly workable. The underlying coals have been little exploited, but will probably yield some workable coal.

Along the crest of the Chestnut Ridge anticline northeast in Indiana county, the Upper Freeport coal is caught only in the few hilltops, but the Kittanning coals should be found here. Further along the anticline, in Clearfield county, where it follows the crest of the ridge, all the coals of the Allegheny formation have been preserved by the massive Upper Mahoning sandstone, the blocks of which completely cover the top of the ridge. Both of the Freeports,

A. Typical mining town.

B. Mining Plant, Washery, coke ovens, etc.

Plate XII. Mining conditions in Pennsylvania.

the Lower Kittanning and the Brookville coals appear to be of workable thickness under part of this ridge.

The district between Richmond and Deckers Point south and west of Little Mahoning creek, contains all of the Allegheny coals in the hills. The coals, as a rule, lie above drainage. The Freeports are of workable thickness. The Upper Kittanning, north of Deckers Point, has associated with it an irregular bed of cannel coal with a maximum thickness of 9 feet. The Lower Kittanning appears to be generally of workable thickness. It reaches 5 feet or more just southwest of Richmond.

The Brookville coal is the most prominent coal in outcrop in the district around McGees on the southeast of the Chestnut Ridge anticline. It is of variable thickness, though it attains a thickness of 4 feet in many places. It usually has some partings of bone or shale. This coal keeps just above drainage up Bear run and Whiskey run. The Kittanning coals occur in the hills in small body. The Freeports have been removed from most of the district.

In the district about Glen Campbell coals "E," "D" and "B" are mined commercially. Coal "E" has a thickness of from 3 feet or less to 4 feet or more, often without partings, though in many places it has about 4 inches of bony at the top, and as much, or more, at the bottom. The "D" coal is more variable in thickness and position and locally north of Uray it has a thickness of 16 feet. In some of the mines, as in Glenwood No. 6, it maintains a uniform thickness of 4 to 5 feet, without partings, but in a short distance it may thin down to 2 feet or less. At many points it contains bands of bone 6 to 18 inches thick that come in the body of the coal as well as at the top and bottom. The "B" coal is mined in Horton run, and it appears to be workable under most of this district.

In the district southwest of Glen Campbell, about Gipsy, Arcadia and Wilgus, and northwest and west of Hillsdale, practically all mining is on the "E," or Upper Freeport, coal. Coal is at drainage level at Arcadia, but rises rapidly to the westward until it just underlies the Little Mahoning-Cush creek divide. All through this district this coal maintains a very unusual uniformity of section. Nearly everywhere there is from 3 to 8 inches of bony coal on top in place resembling cannel coal, then a main bench of from 38 to 48 inches, a 1 to 2-inch parting, and a bottom bench of from 3 to 6 inches. The roof is always shale. The Lower Freeport, though thin (2 to 3 feet), appears to be persistently workable in this district. Some lower coals from 3 to 4 feet thick have been assumed to be at the horizon of the "B" coal, suggesting that that coal will prove generally workable over the district.

In the Burnside district lying south and east of Cush creek and east of Susquehanna river, the coals are, in the main, below drainage and deeply buried. Outcrop exposures and drillings indicate that the "E," "D" and "B" coals will be locally workable in this district, and they may prove to be generally so, but the evidence is not altogether favorable, especially along the south and southeast edges of the quadrangle* much uncertainty was expressed about the correlation of the coals at Rossiter and in the southern part of the quadrangle around Glen Campbell and Arcadia. The difficulty arose from the fact that the first coal being worked lies from 60 to 70 feet below the base of what was considered to be the Mahoning sandstone, and that immediately under the sandstone there are traces of coal, clay and ferruginous limestone. The latter were, therefore, considered to be at the horizon of the Upper Freeport coal and the first workable coal to be the Lower Freeport. Later field work has shown beyond doubt that the sandstone is the upper member of the Mahoning, that the thin coal, clay and ferruginous limestone below it belong to the position of the Mahoning or Johnstown ore horizon; that the position of the Lower or Upper Mahoning sandstone is nearly over all of this quadrangle, as well as over several adjacent quadrangles, occupied by shale, and that the main coal at Rossiter and the uppermost coal at Glen Campbell are undoubtedly the Upper Freeport.

CURWENSVILLE AND HOUTZDALE QUADRANGLES.

The coals of these quadrangles belong to the Allegheny formation. As given under Stratigraphy, there is found here a marked increase in the number of coals of this formation, but in the main the number of workable coals continues about the same as in the other quadrangles. Both of the Freeport coals are workable, the Lower Freeport being much the most important coal in the area. The Middle Kittanning coal is workable in the region north of Gearhart and west of Morrisdale, and in a few other places locally. The Lower Kittanning is quite widely workable, though over much of the area it is badly split up—so much so that it will not be worked under the present conditions. The Brookville, or Clarion, coal is also workable over parts of the quadrangles. The coals of these quadrangles are of exceptionally high grade, verging on the semibituminous type. One effect of this is that a large amount of mining is carried on in beds that do not average more than 2½ feet, and in some cases mining has been continued until the bed has decreased to a thickness of 18 inches or less. In the Houtzdale quadrangle, between Houtzdale and Osceola, is the original Moshannon basin, which has furnished the famous Clearfield coal of commerce.

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*U. S. Geol. Surv. Bull. 285, pp. 276-279.

HOUTZDALE QUADRANGLE.

Moshannon Basin. This basin includes the coal lying on Moshannon creek and Beaver run and extending in a general way from Houtzdale to Osceola on this quadrangle, and past Philipsburg and Morrisdale, east of the quadrangle. It has furnished most of the coal known on the market as Clearfield coal, and is still supplying a large portion of that coal, though, as a matter of fact, much of the coal along the Allegheny Front of somewhat similar character is being shipped to the market as Clearfield coal. The Lower Freeport or "D," or the Moshannon, as it is locally called, is the bed that has supplied this coal in the past. It has a thickness all through this basin of from 4 to 6 feet, running occasionally much over the upper figure and averaging about 5 feet. While generally the coal is without partings, there is often found ½ to 1 inch of cannel or rich bone about 2 feet from the bottom, and sometimes there is a small bench of coal above or below the main bench. Probably one-half of the measured sections of this coal about and northwest of Osceola show a bony top from 2 to 10 inches thick, which in many places is overlain by clay. Northwest of Houtzdale there is frequently an upper bench of coal from 6 to 24 inches thick, separated from the main bench by from 4 to 6 inches of clay or shale. A fall in the roof at one mine showed this upper bench to be 64 inches thick, with still above 9 inches of clay, then 9 inches of coal. The roof is usually shale, but, as previously described, is often bone and clay, and in some of the mines along Whiteside creek, is sandstone. The floor is clay. While the heart of the seam in this basin has already been taken there is still some coal left around the edges and in the center, where in the early days tracts of coal, slightly inferior in thickness and quality, were passed by. These remnants are being rapidly removed by a large number of shipping mines. There are still a few large mines operating in this field, but apparently on bodies of coal which have passed or are approaching exhaustion. Some 45 feet above the Moshannon seam is the "E," Upper Freeport, or "cap" seam, as it is locally known. In this basin it is of poorer quality than the "D" coal and has a thickness of only 3 feet. At present it is mined only on a small scale. It underlies nearly the same areas as the Moshannon seam. Below the "D" seam coals which are locally workable occur at four different horizons. The first is over 100 feet below and correlated as the "C^1" and shows 3 feet in places, with a local thickening of up to 6 feet or more, due to the presence of several feet of cannel coal. Cannel coal is mined from this bed on Moshannon creek and near the mouth of Whiteside creek, but, as shown, the extent of the deposit appears to be quite limited. The "B" coal lies about 165 feet below the "D" coal, and shows a thickness of from 2½ to 6 feet. As a rule, it is broken up with partings and tends to carry a larger percentage of sulphur and ash than the "D" coal. This coal often shows three benches, of which only the upper two are worked in the region between Osceola and Powellton and along Whiteside creek. The parting is usually bone, but in places it is clay or sandstone, having a thickness of from a few inches up to 4 feet. The middle bench is commonly 3 feet or more thick, and below it is a parting which is often several feet thick of hard, gnarly clay, below which is a bench of 18 inches of coal. There is generally a thin rider over this bed and within 20 feet of its top. A typical section of this coal near Osceola shows: Shale, 3 to 14 feet (under sandstone), making a good roof; coal (short-grained), 18 inches; shale, 2 inches; coal (long-grained, except at top), 39 inches; clay and sandstone, 8 to 18 inches; coal (very sulphurous), 10 to 14 inches; clay floor. Going toward Powellton, the main bench reaches 4 feet. In the New Monarch Coal Company's shaft what is supposed to be the "B" coal is 5 feet, and over, thick, with 2 feet 6 inches, or more, of coal only 10 feet above. About 220 feet below the "D" coal is the "A¹" coal. While thin in places, this bed shows a thickness of up to 6 feet. Over parts of the district it shows two regular clay bands, but generally has many thin, irregular streaks of dirt, and is very sulphurous. The section southwest of Osceola showed 46 inches of coal with two 1-inch bone bands 10 inches from the top and 18 inches from the bottom, with 6 inches of bone on top of the bed. Similar sections were noted south of Osceola, except that the partings were shale or clay.

Muddy Run District. The second district includes the coal on the Muddy run drainage above Banian Junction. It is characterized mainly by the splitting of the "D" or Moshannon bed. West of Houtzdale this coal becomes irregular and locally wanting, but it recovers a little further west, only to split into two benches which may be as much as 55 feet apart. The beginning of this split may be observed in several of the mines in a line running northwest and southeast from east of Smoke run to west of Banian Junction. In one case the parting increases in a distance of 30 feet from 6 inches to 4 feet 2 inches. In another mine, the parting changes from 2 inches to 8 feet and back to 1 foot in a distance of 250 feet. See fig. 11. Going southwest from this line, the separation becomes more pronounced, until, as stated, they become too far apart to mine together, and mining is continued only in the lower bench. In most of the mines of this district this lower bench which is mined averages but little over 30 inches thick, but as it maintains the excellent quality of the coal in the first district, it finds a ready market and can be worked with profit. This coal appears to run fairly regularly over the whole district. The upper bench and the "cap" coal are both thin—2 feet or less. As the lower bench of the "D" coal is near drainage in this district, no mining has yet been done on the underlying beds, and but little is known of them. Drillings indicate one or two beds below of fairly workable thickness in places, though locally there appears to be no workable coal below the lower bench of the Moshannon.

Madera District. This district includes the territory around and to the north of Madera, and is characterized from the preceding districts by the fact that the coals and their accompanying rocks rise so that the Freeport coals occur only in the hilltops, and all of the underlying coals are exposed. The Moshannon coal in this district has been largely removed, so that mining at present is on one of the lower coals, probably about in the position of the Clarion, as there is a small coal below it which may correspond to the Brookville. The mined coal shows a thickness up to 4 or 5 feet, but often carries a large amount of cannel-like bone near the top. There is usually one thin parting and occasionally two. The "B" coal in the Houtzdale district has been worked to some extent south of Madera, where it shows a thickness of about 3 feet. All of the coals rise toward the north, so that the uppermost coals are above the hilltops north of Belsena Mills.

Northern Half of the Houtzdale Quadrangle. In general the northern half of the Houtzdale quadrangle is characterized by the fact that the great dome between Belsena Mills and Bigler has lifted the rocks so that the Allegheny formation with its coals is mainly in the hilltops or entirely eroded. The Freeport coals occupy the hilltops between Susquehanna river and Little Clearfield, also the crest of the divide between Little Clearfield and Clearfield creeks. Along Susquehanna river and Little Clearfield creek the bottom of the Allegheny comes just at drainage level. Going eastward, the rocks rise, keeping just above drainage up Roaring run over the crest of the anticline near Bigler, and then descend to the southeast so as to keep just above Laurel run. Southwest of Bigler and west of Blue Ball the anticline or dome is high enough so as to raise the whole of the Allegheny formation above the hilltops in many places. The Moshannon or Lower Freeport coal is commercially worked at Devling, Glen Richey and near Susquehanna Bridge. The extension of the Houtzdale-Osceola basin on this coal just touches the eastern edge of the quadrangle southeast of Blue Ball, where the coal maintains the same excellent thickness as around Houtzdale, but has now been entirely worked out. Around Glen Richey and Oshanter the "D" coal will range from 30 to 40 inches, with ½ to 2 inches of shale 5 to 10 inches from the bottom, and usually with a bony layer on top. The "E" coal has been opened at many places northwest of Clearfield Bridge, where it has a thickness of about 30 inches. The "C^1" coal is worked near Woodland, where it has a thickness of about 3 feet, overlain by 10 inches or a foot of bony coal. Eighteen feet above this coal is a small coal 1½ to 2 feet thick. Southeast of Blue Ball the "C^1" has been opened at the Guion mine, where it shows a thickness of 4 feet 4 inches, including from 1 to 2 inches of bone and shale 6 to 7 inches from the top. On the road north from Graham Station, just off the eastern edge of the quadrangle, there are five Kittanning coals exposed in an excellent section at that point. The "B" coal is opened around Blue Ball along Little Clearfield creek and on Susquehanna river. It nearly everywhere shows a solid bench of coal from 2 feet to 3 feet in thickness, often running under 2 feet. It is usually characterized by being underlain with a good thickness of fine clay. In parts of this district this clay runs from 5 to 15 or 20 feet in thickness, a part of which is a high grade flint clay. Along Little Clearfield creek, at a distance of from 65 to 95 feet below the "B" coal, is what has been assumed to be the "A" coal, which there shows a thickness of 3 to 3½ feet. It is characteristically underlain by a foot of coal separated from the main bed by 4 or 5 feet of clay. In descending Little Clearfield creek the interval between these two beds appears to decrease until south of Clearfield Bridge they are only 22 feet apart, the upper coal, as usual, being a solid coal 2 feet thick, while the lower is a 3-foot coal, in 3 benches, with a bench of coal below from 10 to 16 inches thick, separated by from 5 feet to 15 inches of clay. Crossing to the region about Blue Ball, there is a somewhat similar coal below what is considered the "B" coal, but it is there only 14 or 15 feet below the "B" coal. In the region about Blue Ball this lower coal, which, with much question, may be designated the "A" coal, shows a thickness of about 40 inches, with 1½ inches of bone 15 inches from the top. Over the coal is frequently found from 2 to 3 feet of clay, with from 0 to 12 inches of coal above that. This clay in many places forms a treacherous roof tending to come down badly.

At one place in Blue Ball this coal was 5 feet thick but was cut out in a few yards by the sandstone roof coming down, the coal and sandstone interleaving at the contact. A somewhat similar thickness appears on the high ridge west of Blue Ball. A coal supposed to be the same as this runs over 3 feet thick around Boardman with a clay and shale roof. To the north of Boardman this bed shows from 3 feet 6 inches to 4 feet of coal with shale roof.

CURWENSVILLE QUADRANGLE.

Grampian District. North of Susquehanna river and east of Bell run in this district, the "D" coal appears to be persistently workable. It occurs well up in the hills going above the hills to the north. West of Grampian this coal shows a thickness of 5½ feet with a 2-inch parting 14 inches from the top and 2 inches of splinty coal 3 feet 4 inches from the bottom. Throughout this district as a whole this coal runs from 3 to 3½ feet thick. In most cases it shows a parting of 1 to 2 inches of clay or shale or sometimes bone, 2 to 5 inches from the bottom. About 40 feet above the "D" coal is the "E" or Upper Freeport, which is mined commercially only at one point, just west of Grampian. Here it is from 34 to 36 inches thick. At other places in this district it does not appear to run much over 2 feet and often is not that thick. The "B" coal in this district is a small solid coal 18 inches to 3 feet thick, not including irregular benches below. Northwest of Grampian it shows a thickness of 2½ feet. Just across the edge of the quadrangle on Hughey Run it shows a thickness of up to 42 inches, with 14 inches of coal 3 feet below. As far as seen, the other coals of the section are not workable in this district.

West of Bell run the hills are largely uninhabited and the region has been but little prospected. The Chestnut Ridge anticline crosses the northwest corner of the quadrangle and carries the coal up so that the Upper Freeport coal appears to lie just under the top of the ridge, the coal rising in the ridges as they recede northwestward from the river. This is in part due to the fact that the upper member of the Mahoning sandstone forms the crest of many ridges, preserving the coal measures below. The Freeport coals are well determined and are of workable thickness just off the quadrangle to the west. In this district the small amount of data indicated that one or another of these coals would yield 2½ to 3½ feet of coal, with a local thickening reported up to 6 feet. Twenty-nine inches of solid coal was measured in about the "B" horizon and it is quite probable that this bed will prove workable over much of the district. The "A" coal has a workable thickness just west of the quadrangle, though it is rather poor and irregular, but it will probably be workable over part of the area.

Little Clearfield District. At Olanta the whole of the Allegheny formation lies in the hills above drainage and much the same condition holds over the district. The lower coals pass below drainage around Gazzam. The hills are high enough to cover a good body of even the upper coals, and the lower coals underlie practically the whole district. In this district the Upper Freeport coal ranges from 2 to 2½ feet in thickness with shale roof and clay floor.

The "D" coal is extensively mined around Gazzam and has been used at many points in the district. It shows an average thickness of 2½ feet, ranging up to 4 feet in places. In most places it shows a characteristic parting of ½ inch to 2 inches, coming from 2 to 6 inches above the bottom. At a few points near New Millport this coal has 6 to 8 inches of bony coal on the top. The "B" and "A" coals in this district, so far as seen, resemble the same coals in the portion of Little Clearfield creek drainage of the Houtzdale quadrangle, the "B" being a moderately thick and solid coal, the "A" tending to have a thickness of 3 feet underlain by 2 inches to 1 foot of coal, 2 to 5 feet below.

Clearfield Creek District. This district includes the southwest corner of the quadrangle lying southeast of the Ansonville-McPherron road. The base of the Allegheny formation is just above the drainage at Irvona and Rosebud. At McCartney and Berwinsdale only the upper coals are above drainage, so that the lower coals underlie practically the whole of the district and the higher coals have a large body and are well protected. The "E" coal shows a thickness of 5 feet northeast of McCartney though it is inclined to be dirty. In general it is much thinner. It is mined commercially at McCartney where it is 32 inches thick, and it has about the same thickness around Glen Hope. The Lower Freeport or "D" coal around McCartney has a thickness of 4 to 5 feet or more in several of the mines, in some cases with a small bench 1 foot above the main bench. Around Glen Hope and Irvona this coal has a thickness of 30 inches to 3 feet. At Berwinsdale it is mined commercially, its thickness being 3 feet or over, usually without partings though locally showing a characteristic shale parting 8 inches from the bottom.

The "B" coal is extensively mined at Coalport (Rosebud) and Frankhurst. It has a thickness of 5 to 6 feet around Coalport. It is variable in thickness ranging from 4 feet without partings to 6 feet with usually two shale and clay partings. Often these partings are 6 to 8 inches or even up to 14 inches thick., The roof has often 8 feet of clay overlying it and over that is black shale with sandstone still above. The sandstone often comes down and cuts into the coal. Going from Coalport to Irvona the coal splits. The two benches are 9 feet apart near Irvona and are reported to be much farther apart to the northwest.

Chest Creek District. The Allegheny formation outcrops in the lower slopes of the hills along Chest creek, the lowest coals being below drainage. The "E" coal is worked at La Jose where it has a thickness of 2 feet 8 inches to 3 feet 8 inches. It has a binder 8 inches to 1 foot from the bottom. It has about the same thickness at Ostend. Apparently the same coal at St. Lu reaches a thickness of 6 feet 7 inches, but it is badly split up with partings. This condition seems to extend southward to Waukesha, though with a reduction in the thickness of the coal. The coals of this district as a whole do not promise well. As a rule the thicker coals are badly split up with partings, often so as to be unworkable commercially, while the coals not so badly split up are in the main thin,—20 to 30 inches usually. On account of the thinness of the coals and the lack of any sandstones or rocks that would serve as stratigraphic aids, the stratigraphy of the coals of this district have not been well worked out.

PETROLEUM AND GAS.

By M. J. Munn.

Introductory Note. The work of the geologist in connection with the production of oil and gas is in six or more lines. He has first to learn the stratigraphy of the oil and gas-bearing rocks; in other words, to learn how many sandstones or other rocks in any area are oil or gas producing, and the character of each rock as to kind, color, fineness or coarseness of grain, etc.; how far they are apart; how thick they are; whether they thicken or thin in any direction; whether the distance between them remains constant, and if not, just how and how much it changes; to what outcropping rock the oil or gas bearing rocks correspond; what age they belong to, so as to determine in what ages oil and gas bearing rocks occur; the correspondence between the sands of one pool and those of another, etc., etc.

In the second place he will work out the structure of the region under development and will then study carefully the relation of the productive wells to the structure as he has worked it out.

In the third place he will learn everything possible about the occurrence of water in the wells and in the producing sands, and the apparent relations between the occurrence or abundance of water and the productiveness of the wells. He will learn all he can in regard to the pressure or head, both the original head, after equilibrium has been established, and at later dates; the effect of new wells on the pressure or head of old wells, etc., etc.

In the fourth place he will learn the kind and quality of the product of each well, physically, chemically and commercially; any variations in these elements from time to time or from well to well, or from pool to pool, or between the products of one sand and those of another, and the association with the primary products of secondary substances.

In the fifth place he will study both microscopically and chemically the character of the oil and gas bearing strata, and the strata above and below, to determine if possible the source of the oil and gas.

In the sixth place, with all of these data in hand he will then attempt to put these different facts together to see if he can find any relationship between certain groups of facts and others; for example, he will try to determine whether the oil and gas producing sands are restricted to rocks of certain ages or certain kinds; if he finds them to be so restricted he can then block off certain areas on the map and can say, so far oil and gas have not been found in the rocks of the age or kind that underlie these areas, or he may say in regard to a proposed drilling at any place, you are risking failure if you drill below so far, for at that depth you will reach rocks in which no oil or gas has ever yet been found. Or, on the other hand, he can say of a certain area, this area is underlain by rocks that are oil or gas bearing in other places; and of any place he can say, at this place it is approximately so many feet or hundreds of feet to such and such a sand which is oil or gas producing in some neighboring region.

In his study of the structure he will attempt to discover if the productive wells are confined to particular parts of the structural folds. If he finds that they are he can then say, after having worked out the structure in undeveloped area, the productive wells appear to lie near the axes of the anticlines; therefore drill near the axis of this anticline as I have determined it. If such a relation seems to exist sometimes and sometimes not, he will then seek to discover what other factors are involved and in what way. He may find that where the sand is saturated with water the productive wells show a certain definite relation to the structure, and where the sand is not saturated they show some other relation.

These are but a few of the hundreds of relationships that have to be compared and studied. It is evident at once that were the geologist able to solve all of these problems he could reduce the risk of the oil and gas business to a minimum.

It has always been true that a half truth may pass as true as long as you know no exceptions to it. An increase in knowledge is always liable to contain the exceptions that upset the rule. Again it is often true that an increase in the number of facts may not only upset old rules or conceptions, but because they are still only partial, may give a confused view of existing relations that can only be cleared up by a much larger number of facts or by a complete knowledge of the facts. Our knowledge of the relations that have determined the occurrence or accumulation of oil and gas in the Appalachian field is at present much in this intermediate condition. Accurate delineation of the structure has for the first time allowed both a close and a broad study of the relations of the accumulation to the structure. The recent work in southwestern Pennsylvania, particularly the work of Mr. Griswold, and even more especially the recent work of Mr. Munn, has shown that when the data are plotted on a large scale map, where the structure is shown by 5 or 10-foot contours, and each sand considered by itself, the conditions are much more complicated than had ever been suspected.

The amount of data used may be suggested by a few figures. Thus, in the Sewickley quadrangle, and the same is true of some other quadrangles, in the neighborhood of 2,000 drill holes have been accurately located. Of these the records of about three-fourths have been obtained, and of about half more or less detailed information as to the water conditions, etc., has been secured. To digest all of these facts so as to arrive at any definite or general conclusions is a task that may easily be imagined. The graphic method has been largely used in the study of these facts. All the data of a single class has been put upon a single chart and grouped with other facts to determine their relations. Already certain relationships seem to be coming out as a result of these studies and others are dimly foreshadowed. The great bodies of facts are awaiting the acquisition of more facts before they will fall into groups. This need of more facts is emphasized by Mr. Munn's paper which follows:

G. H. A.

The quadrangles in which geologic work has been done by the State Survey in co-operation with the United States Geological Survey, embraces some of the greatest oil and gas pools yet discovered in the Appalachian fields. In the development of each of these pools it is greatly to be deplored that conditions did not permit detailed scientific investigations to accompany, and whenever possible, direct the drill. The failure of science to fortify itself with the abundant facts then available has resulted in an irreparable loss to itself, and an equally great financial one to producers. It is quite certain that if the most had been made of all data brought to light by the drill, the geologic history of these great accumulations of oil and gas would now stand revealed, and this revelation would have resulted in the saving of millions of dollars in the development of these accumulations.

In a sense, it has been unfortunate that plausible theories accounting for the origin and mode of occurrence of petroleum and natural gas have been so easily formulated, and apparently as easily proven. This has not been conducive to exhaustive study of the deposits by geologists, and has led to the confusion, and frequently to the disgust, of producers who have attempted to religiously follow a theory in one section where the geologic conditions (which they did not observe or understand) were entirely different from those in another region where that theory had proven eminently satisfactory. In recent years it has become more and more apparent that this atmosphere of uncertainty can be cleared only by a broad and exhaustive study of all available data, not only from the fields of Pennsylvania but from those of the entire Appalachian region.

An immediate and more pressing need for scientific investigation of our petroleum and natural gas resources lies in the fact that this source of heat and light is rapidly becoming depleted. The common good demands that every safeguard be exercised to prevent losses in the production and waste in the utilization of these fuels.

Recognizing this fact, geologists and producers are now of one mind that it is the duty of the State and National governments to facilitate in every way possible any commendable effort looking toward this end in the belief that it is the duty of this generation to leave to posterity a creditable scientific and economic history of these remarkable deposits.

GEOLOGIC CORRELATION OF THE PRINCIPAL OIL SANDS OF PENNSYLVANIA.

	Driller's Name.	Geologist's Name.
Monongahela,	Pittsburg coal,	Pittsburg coal.
Conemaugh,	Murphy sand,	Morgantown sandstone.
	Little Dunkard sand,	Saltsburg sandstone.
	Big Dunkard, Hurry-up or Cow Run sand.	Mahoning sandstone.
Allegheny,	Gas sand,	Kittanning, Clarion or Homewood sandstone.
Pottsville,	Salt sand Sixtyfoot,	Connoquenessing, or Pottsville sandstone.
Mauch Chunk,	Little lime, Salvation, or Maxton sand.	Greenbrier limestone.
Pocono,	Mountain, or Big Injun sand,	Burgoon sandstone.
	Squaw.	
	Papoose.	
	Butler gas, Butler 30-foot, gas, Salt, Murrysville, or Berea (?) sand.	
	Gantz and Fiftyfoot or Hundredfoot sand.	
Catskill,	Nineveh 30-foot or Thirtyfoot sand.	
	Snee, Blue Monday, or Straystray sand.	
	Boulder, Gordon Stray, or Campbell Run (?) sand.	
	Gordon, or Third sand.	
	Fourth sand.	
	Fifth (McDonald) sand.	
	Bayard, or Sixth sand.	

	Driller's Name.	Geologist's Name.
Chemung,	Elizabeth sand.	
	Warren first sand (?).	
	Warren second sand (?).	
	Speechley sand.	
	Tiona sand.	
	Bradford First and Second sands.	
	Elk (?) sand.	
	Kame (?) sand.	

REVIEW OF WORK DONE IN OIL AND GAS IN CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.*

MASONTOWN-UNIONTOWN QUADRANGLES.

The first geologic work in the oil and gas fields of Pennsylvania to be done in co-operation with the United States Geological Survey was that on the Masontown-Uniontown quadrangles, 1900. At that time the only fields of importance within the quadrangle were the newly discovered Haddenville, the Masontown, Fayette and New Geneva gas fields and the Mt. Morris-Mannington, Whitely Creek and Blackshire oil pools. No oil or gas to that date had been found on the Uniontown quadrangle.

Haddenville Gas Field (16).† At the time of the publication of this report the Haddenville pool consisted of seven gas wells producing from the Gantz and Fifty-foot sands and two from the Big Injun.

Fayette Gas Pool (15). The production from this pool comes from the Big Injun, the largest well being found on the Ryder farm located on the north branch of Brown's run, about one mile southeast of McClellandtown.

Masontown Gas Field (14). In this field the gas is mainly obtained from the Gantz, though a few wells have considerable gas in the Big Injun. In the New Geneva field (13), which at that date contained only four wells, the gas was mostly derived from the Big Injun, a single well having gas in the Fifty-foot sand.

Mt. Morris Oil Field (9). Only the northern portion of this oil field is embraced by the Masontown quadrangle, the greater part of it lying to the south in West Virginia. In this field oil was first obtained from what is probably the Mahoning sandstone of the Allegheny Valley. After this pool was exhausted and the wells abandoned, deeper ones were drilled, getting production from the Big Injun. This field has yielded a large amount of oil, but is now practically exhausted.

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*See bibliography and history of cooperative geologic work in Pennsylvania for data on field work and publications on the different pools.

†The figures refer to the large map where all of the oil and gas pools are numbered.

Whitely Creek Oil Field (11). The oil in this field comes from the sandstones of the Conemaugh formation, principally from the Mahoning or Dunkard sand, which in some wells has yielded as much as 100 barrels per day. Great difficulty was experienced in this field in keeping the wells open on account of the tendency of the soft shales to cave. In 1902 this field was apparently almost exhausted.

Blackshire Oil Pool (12). This is a small pool, the principal well being the Blackshire No. 1, which yielded about 100 barrels per day from the Big Injun sand.

No detailed discussion of the occurrence of salt water in these pools is given. In one or two records water is noted in the Big Injun and the Salt sand.

GAINES OIL FIELD.

The Gaines oil field is not shown on Plate 1. It is located in the western part of Tioga county, about 17½ miles from the New York State line, and is the most eastern oil field in Pennsylvania.

The Gaines field consists of the Watrous pool producing from the Atwell sand, and the Manhattan pool, which gets its oil from the Blossburg "Formation." These oil-bearing beds are in the Chemung formation at about the horizon of the Bradford group. The largest well in these pools produced 2,100 barrels the first day from the Blossburg formation, but declined rapidly, as do all the wells from this horizon. The wells in the Atwell sand come in small, but hold up well.

This field was pretty clearly outlined in 1901, having about ninety producing wells. The pools lie along the southern limb of the Pine creek syncline, occupying the top of a monocline or bench, with the "break" toward the north. Salt water is found in the producing sands down the slope from the oil and gas in the dry sand above. This is an instance where the water in the oil sand has apparently reached a state of equilibrium and the oil and gas have had time to arrange themselves in the sandstone with reference to gravity, the water below, and the gas above.

BROWNSVILLE AND CONNELLSVILLE QUADRANGLES.

Only a general study was made of the oil and gas resources of these quadrangles.

No oil pools had been discovered within this area at that time, and no gas on the Connellsville quadrangle.

The gas pools on the Brownsville quadrangle conform closely to the structure, the important pools lying along or near the crests of the anticlines. At the time this report was written there were three well-defined gas pools within the quadrangle.

Bellevernon Gas Field (19). This field extends southwestward along the crest of the Bellevernon anticline from the vicinity of Smithdale to the south fork of Maple creek. In this field the gas comes principally from the Big Injun, Gantz and Fifty-foot sands. The maximum rock pressure was about 850 pounds, from the Fifty-foot sand.

Centerville Gas Field (18). This field is situated on the pitching crest of the Bellevernon anticline near the southwest corner of the quadrangle. In it nearly all the gas comes from the Fifty-foot, though some comes from the Elizabeth sand.

Forward Gas Field (20). This gas is found in the Big Injun, Gantz, Fifty-foot, Gordon and Sixth sands, the Gordon sand leading. This field was opened up in 1900. Some of the wells produced as much as three million cubic feet per day. It is located on a local anticline in Forward township, west of the Pigeon creek syncline.

In this paper (U. S. G. S. Folio 82) no mention is made of the occurrence of salt water in the deep sands, except that brine for the manufacture of salt was obtained from a number of shallow wells drilled on the Connellsville quadrangle, south of Sewickley creek, from Hunkers to Emmonston. It is to be regretted that an attempt was not made to trace the horizons carrying salt water from east to west across these quadrangles, and to secure data regarding the capacity and head, at different points. This would probably assist greatly in explaining the peculiar water conditions in the oil sands in areas further to the west. It is not improbable that the Pocono formation, exposed along the axis of the Chestnut Ridge anticline in the Uniontown and Connellsville quadrangles and to the east, has served as a catchment area, from which meteoric waters have penetrated to the Catskill formation in the Claysville and Waynesburg quadrangles. It seems easily possible for water traveling that distance through rocks of this kind to take up in solution the percentage of salt found in it.

INDIANA QUADRANGLE.

At that time (1901) no oil had been found in paying quantities within the quadrangle, and but two small pools of gas.

Willetts Gas Pool (85). Most of the Willetts pool lies to the west of the Indiana quadrangle, along the crest and flanks of the Roaring run anticline; but in 1890 and 1891 six producing wells were drilled on an extension of this field to the northeast. These wells are located on the south fork of Plumb run in the vicinity of Willetts. The producing sand is from 15 to 25 feet thick and lies about 1,100 feet below the Upper Freeport coal. This sand was not correlated with the oil sands further west, but it probably belongs to the Pocono formation and is possibly equivalent to the Murraysville sand. The rock pressure in these wells varied from 275 to 350 pounds, the maximum minute pressure reaching 245 pounds, 6¼ inch casing. In one well the closed pressure diminished from 275 pounds in 1891 to 100 pounds in 1901.

Creekside Gas Pool (84). The Creekside pool in 1901 consisted of four producing wells and three dry holes. The rock pressure was about 325 pounds, and minute pressure 105 pounds in 4-inch casing. The gas probably comes from the same horizon as that of the Willetts pool.

Hundred-foot contours on the Upper Freeport coal show the Willetts pool to be located on the flank of the Roaring run anticline, and the Creekside pool similarly situated midway between the crest of the McKee run anticline and the Elders Ridge syncline. Since no mention is made of the presence of salt water in this field, it is not possible from the other data at hand to state how closely these pools conform to the anticlinal theory.

LATROBE QUADRANGLE.

The next geologic work done by the State of Pennsylvania in cooperation with the United States Geological Survey within the oil and gas region was that for a folio of the Latrobe quadrangle, which lies to the northeast of the Connellsville and to the southwest of the Indiana quadrangle.

At this time (1901-1902) oil in paying quantities had not been discovered within the area, and but a single gas pool of limited extent. This pool (115) occupies the crest of a dome in the Fayette syncline lying three miles west of Latrobe.

No mention is made of the producing sands nor of water conditions in the deep sands as determined by drilling. Nothing of importance regarding oil and gas was learned, except that the pool discovered occupies the crest of an anticline.

KITTANNING AND RURAL VALLEY QUADRANGLES.

In 1902-1903 the entire production of oil on the Rural Valley quadrangle came from two small wells located about three miles southeast of Kittanning. The first oil found on the Kittanning quadrangle was probably that from a well at Brady's Bend (92) drilled in 1865.* At this place as many as 14 wells were drilled before 1871, getting some oil and gas. Aside from this pool the oil-producing areas are confined to the western quarter of the Kittanning quadrangle, from Karns southward to Rough run (93). These fields were developed between 1873 and 1875. Many of the wells produced from 100 to 2,000 barrels per day, the total production being very large.

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*Am. Phil. Soc., Proc., vol. 10 pp. 227-241, and vol. 12, pp. 562-570.

The Stray, Third and Fourth sands are the great oil-bearing beds of this field. Contours on the Vanport limestone show that these pools are situated at and near the bottom of the Brady's Bend syncline.

The Murrysville, Hundred-foot, Thirty-foot, Fifth, Speechley and Tiona sands have been a prolific source of natural gas within these quadrangles. Pools in these sands occur on the crests and slopes of the principal anticlines, and sometimes well down in the troughs of the synclines. In the latter cases, however, the pools are of secondary importance, the synclines being generally barren. Many single wells have produced more than a million cubic feet per day, the maximum for a single well being probably 30,000,000 cubic feet. The gas pools of these quadrangles are discussed by the author as follows:

"*Gas Fields.* The gas-bearing territory of the quadrangles is more or less completely separated into several fields by areas of comparatively unproductive territory. These are the Winfield field (94) lying in Winfield, West Franklin and North Buffalo townships; the Madison field (97) lying in Madison, Washington and the northern part of East Franklin townships; the Glade Run field (95) lying to the west of Glade run in eastern North Buffalo and southern East Franklin townships; the Limestone Run field (96) near the mouth of that stream, and the Cowanshannock field (98), including most of Kittanning, Cowanshannock, Valley, Boggs and Wayne townships. In addition to these there are several smaller fields—one just east of Ford City (99), one along Garrett run (100), one at Atwood (101), another north of Mahoning Furnace (102), and one in Redbank township in the northeast corner of the Rural Valley quadrangle (103). All these contain comparatively few wells, and the product of these is generally not large. The one east of Ford City developed in 1902, is the most important. A number of good wells were drilled, but the field proved to be of small extent.

Gas does not occur in the deepest parts of the synclines, though there are some apparent exceptions to the rule. In the vicinity of Slate Lick (104), a few paying wells have been drilled to the Speechley sand in the bottom of the Boggsville syncline. Even here, however, the rocks are rising from the deeper part of the syncline to the locality of the well. A number of good wells were obtained in the Murrysville sand at Ford City, near the axis of the Fairmount syncline, but they are 100 feet above the bottom of the syncline. The two wells on the Starr farm south of Hays run are on the axis of the Fairmount syncline, but on the crest of a low cross anticline that separates the depression on Pine creek from the portion of the syncline farther south. The wells in the vicinity of Mosgrove and on Garrett run, though near the synclinal axis, are still about 100 feet above the bottom of the basin. Southeast of Blanco there are two light wells in the Apollo syncline, but here again is a low cross anticline. In the vicinity of Rural Valley there are a few wells in the flat-lying strata fringing the base of the Greendale anticline, but dry holes have been the general result of drilling at greater distances from the anticline. Near Atwood a few wells have been obtained, but the records of these wells indicate a slight anticlinal structure at that place. The wells in the northeast corner of the Rural Valley quadrangle are near the crest of a pronounced anticline."

The somewhat detailed study of the occurrence of oil and gas on these quadrangles, together with the excellent stratigraphic work done, has been and will be of much value in broader studies of these deposits throughout the State.

WAYNESBURG AND ROGERSVILLE QUADRANGLES.

The Waynesburg quadrangle lies west of the Masontown, and is bordered on the west by the Rogersville. These two quadrangles lie almost wholly within Greene county and embrace a number of the largest gas pools yet found in Pennsylvania. Field work for a folio on the Waynesburg quadrangle was mostly done in 1902, by Ralph W. Stone, assisted by M. I. Goldman, and the folio published by the United States Geological Survey, in 1905. Field work for the Rogersville folio was completed in 1905 by F. G. Clapp and published in 1907. Later, a large amount of unpublished data was added to that in the folios, and a bulletin on the Oil and Gas Fields of Greene County, Pa., prepared by Messrs. Stone and Clapp, and published in 1907, the field work being finished in December, 1905. This was the most exhaustive discussion of any portion of the oil and gas fields of Pennsylvania to that time attempted in co-operative work, it marks a distince advance in the investigation of these deposits. Attention was given to stratigraphic and structural problems relative to pools of oil and gas, and the probable importance of salt water as a factor in the formation of these pools was pointed out.

A fact noted in this paper, which may ultimately be found of importance in explaining the causes which have led to the accumulation of these bodies of hydrocarbons in certain spots over this area, is that the shallow sands carry oil in the eastern part of Greene county, and from there westward the oil-bearing beds are successively lower and lower in the geologic column. In Dunkard, Monongahela and Perry townships, the pools were found in the Morgantown, Dunkard and Big Injun sands. The Fonner pool (23) in the northwest corner of the Waynesburg quadrangle produces from the Gantz and Fifty-foot sands. Farther westward, the Nineveh pool (17) is found in the Nineveh, or Thirty-foot sand. The Bristoria production (5) comes from the Nineveh and Gordon. At Aleppo (3) the oil comes from the Gordon and Fourth sands with some oil and gas in the Fifth sand. Two exceptions to this, are the Broad Tree (1) pool near the southwest corner of Rogersville quadrangle, which produces mostly from the Big Injun, and the Lantz pool (4) in Wayne township, just off the southeast corner of the Rogersville, which comes from the Fifth sand.

With the data now in hand this fact cannot be explained, though it is possible that a detailed study of the water conditions in the different beds might throw some light on this point. The gas pools do not appear to conform to this rule, though the shallow sands are probably more productive in the eastern than in the western part of this area.

Aside from the economic value of this paper, it will eventually be of great service to the geologist who combines the very widely scattered observations on the oil and gas fields of Pennsylvania into a theory more in unison with the facts as they are found to exist.

ELDERS RIDGE QUADRANGLE.

At the time field work was completed on this quadrangle (1902) more than 260 deep wells had been drilled, resulting in the location of seven or more gas pools. Oil was found in but a single well near Whitesburg, with a production of about two barrels.

The principal gas sands are the Murrysville, Hundred-foot, Fifth, Speechley and Tiona. Structurally, these pools are almost without exception at the crest or well up the flanks of the anticlines.

Willetts Pool (85). Production from Murrysville sand. Initial closed pressure 275 to 350 pounds; maximum initial minute pressure, 245 pounds in 6¼ inch casing. About 25 producing wells. Pool was developed in 1890-91. Closed pressure in 1901, about 100 pounds, with about 18 wells producing.

Plumb Run Pool (86). Production from Murrysville sand; rock pressure, 350 pounds; maximum capacity of a single well between one and two million cubic feet. This pool has been developed since 1898, and consisted of less than 20 wells in 1902.

Say Pool (91). Development in this pool was begun in 1897, the Murrysville and Hundred-foot being the principal producing sands, though some big wells were gotten in Third sand.

The initial closed pressure in Murrysville and Hundred-foot ranged from 350 to 530 pounds. In 1902 the closed pressure was 100 pounds or less.

Girty Pool (87). This pool was discovered in 1895. In 1902 it contained about 45 wells.

Initial rock pressure about 325 pounds.

The majority of these wells were good producers in 1902.

Roaring Run Pool (88). The first well was drilled in this pool in 1894. The gas comes from the Murrysville and Hundred-foot sands. Initial closed pressure ranged from over 300 to over 500 pounds.

Shellhammer Field (89). This pool was developed in 1894 and 1895, and consisted of 30 or more wells in the Hundred-foot, Third and Fifth sands. Maximum initial pressure, 400 pounds in 45 seconds. Closed pressure in the pool was from 120 pounds to 500 pounds.

Rockville Pool (90). Drilling in this pool was begun in 1893. Gas is found in the Murrysville, Third and Fifth sands. These wells showed maximum minute pressure of about 365 pounds, and rock pressure of from 300 to 400 pounds.

BEAVER QUADRANGLE.

This quadrangle, which lies on the western flank of the bituminous coal basin of Pennsylvania, includes three important oil pools and at least one gas pool of considerable extent.

The structure as depicted by contours drawn in part on the top of Ames limestones and in part on the roof of the Upper Freeport coal, does not reveal any clearly defined anticlines and synclines within the area, but shows a remarkable uniformity in the dip of the rocks to the southeast.

Smith's Ferry Field. The Smith's Ferry field lies along the western border of the quadrangle, north of Ohio river, between Smith's Ferry and Ohioville. It is one of the oldest fields in southwestern Pennsylvania, having been opened up in 1860. Oil was first obtained from seepage into Ohio river from a crop of the Homewood sandstone. The first wells were less than 200 feet deep. One well 72 feet deep had a total production of 400 barrels of 29° oil. In 1869 the field probably produced 250 barrels per day. In 1876 there were about 200 producing wells with an annual production of about 35,000 barrels.

The oil-bearing sands are probably the Salt sand. Big Injun, and what is here known as Berea, which is equivalent to the Butler gas sand.

Shannopin Pool (53). This field extends across the southeast corner of the quadrangle, a large portion of the pool being on the

Sewickley quadrangle to the east of the Beaver. This pool was developed in 1886-7. Its total production to January 1, 1887, was 483,000 barrels. Its greatest output was from 1887 to 1889, some single wells producing as much as 400 barrels per day. Many of these wells are still pumping.

The Hundred-foot is the oil-bearing sand of this pool. More or less salt water is pumped in with the oil from this sand. Structurally, the position of this pool differs somewhat from those found in the Hundred-foot sand to the northeast, where the productive areas occupy the crests or flanks of the anticlines.

Hookstown Pool (55). This pool is situated on the western edge of the quadrangle, south of Ohio river and west of Hookstown. It was discovered and opened up in 1889.

The maximum production of single wells probably did not exceed 150 barrels per day.

The oil-bearing bed is the so-called Berea of this vicinity, which, as stated above, probably is equivalent to the Butler gas sand, or Murrysville sand of Butler and Armstrong counties, as recent investigations by Mr. Butts (p. 196), proves fairly conclusively that the true Berea grit of Ohio is the same as the Hundred-foot sand of Pennsylvania. That portion of the Hookstown pool lying within the quadrangle is near the crest of a local arch which apparently extends northwest from Hookstown to Ohio river or beyond. From this it might be inferred that the producing sand carries salt water.

New Sheffield Gas Pool (54). This pool extends from the vicinity of Aliquippa on the Ohio river off the eastern border of the Beaver quadrangle southwest to three miles beyond New Sheffield. The pool has produced an enormous amount of gas from the Hundred-foot sand, some of the wells having an initial daily capacity of as much as 18,000,000 cubic feet. The close pressure ranged from 350 to 600 pounds. The maximum minute pressure of a single well is not known, but in a number of these wells it ranged from 150 to 420 pounds.

The northern end of this pool lies along the steeper part of a slight monocline, but the southern end apparently crosses the shallow trough of a small syncline having a northwest-southeast trend. No data is given regarding salt water, but the Hundred-foot probably carries some water in this pool.

AMITY QUADRANGLE.

The structure of the rocks on the Amity quadrangle has been depicted by fifty-foot contours drawn on the base of the Pittsburg coal, elevations on this having been secured at a great many points from outcrops and in deep wells, with anaroid, and hand level.

In this quadrangle three oil pools, and at least four distinct gas pools have been found, besides several single wells or small groups, that have produced more or less oil and gas.

Washington Oil Field (26). This is one of the largest oil-producing areas in southwestern Pennsylvania. It extends in a continuous belt from Washington six miles northeast, and from Washington westward on the Claysville quadrangle to within less than one mile of that town. This field was discovered December 31, 1884, by the original "Gantz" well in the town of Washington.

At the end of 1885 the field had produced 10,500 barrels. In May, 1886, sixteen wells were in, with a daily production of 4,000 barrels. In June of the same year, this increased to 10,120 barrels per day. The maximum production was reached in October, 1886, with a daily output of 17,549 barrels.

In that portion of this field which lies within the Amity quadrangle the Gantz and Fifty-foot sands have been the most prolific oil producers, though a considerable portion comes from the Gordon sand. There have also been one or two good producers from the Big Injun.

Many of the wells in this field are still pumping from a fraction of a barrel to several barrels per day. In this pool, as in nearly all prolific pools found in the Hundred-foot sand, more or less salt water accompanies the oil. The oil in those wells having little or no salt water is, as a rule, sooner exhausted than those bearing water.

This portion of the Washington pool occupies a long, narrow belt lying approximately on a level along the western limb of the Nineveh syncline. This position of the oil pools in the Hundred-foot sand, which is equivalent to the Gantz and Fifty-foot, is a characteristic one for that sand over Washington and Greene counties and the southern part of Allegheny and Beaver counties.

It is somewhat remarkable that, as a rule, these accumulations occur on slopes at points where the rock appears to have a steeper dip than it has below the oil-bearing areas. This manner of occurrence would apparently bear out the water line theory advanced by Griswold* if it were not for the fact that in most cases the sand on the slope above the oil pool is also saturated with salt water.

Fonner Pool (23) This pool is located in the southwestern corner of the Amity quadrangle and on the adjoining Claysville, Rogersville and Waynesburg quadrangles. It lies along the eastern flank of the Nineveh syncline, well up towards the crest of the Amity anticline. The first well was drilled in this field in 1897. It produced 1,800 barrels per day from the Gantz and Fifty-foot sands. The field was developed in 1897-99 and reached its maximum production in that time.

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*U. S. Geol. Sur. Bull. 318.

On 1903 ten wells were producing in the field, making a total of about 50 barrels per day.

Zollarsville Oil and Gas Field (17). This is the greatest gas pool yet discovered on the quadrangles. It extends along the eastern flank of the Waynesburg syncline, from Beallsville to a point on the Waynesburg quadrangle three miles southwest of Zollarsville. This field is the northward extension of the Waynesburg field of that quadrangle. Oil occurs in only three or four wells along the northwest edge of the pool.

The Elizabeth sand is here the most prolific gas producer, the Bayard sand being second, and in decreasing ratio, the Fifth, Fifty-foot, Gantz and Big Injun, and in a few instances some gas has been found in the salt sand.

From the best information available, it appears that the same phenomenon found in other fields of southwestern Pennsylvania holds good in this area, namely, that the deeper the sand the greater the closed pressure.

In the T. J. John Well No. 1, drilled in 1906 or 1907, on Tenmile creek, two miles west of Zollarsville, a small amount of gas was found in the Elizabeth sand which showed a closed pressure of 600 pounds, and a minute pressure of 75 pounds in a 6⅝-inch hole. The gas in this well blew out in 24 hours, so that the data furnished by it can not be considered entirely trustworthy. This well is also located almost squarely on the axis of the Waynesburg syncline, at which point the Elizabeth sand is about 150 feet lower than it is at Zollarsville. From incomplete records the Elizabeth sand appears to have a rock pressure of between 500 and 600 pounds.

Amity Gas Field (22). This field is shown by a number of scattered wells along the crest of the Amity anticline from Hackneys to within a mile of Lone Pine. The Salt, Big Injun, Gantz and Fifty-foot, Gordon, Fourth and Fifth sands are producers in one or more wells within this field. A well in the small pool lying about two miles east of Lone Pine getting gas from the Fifth sand is said to have had sufficient pressure to raise the casing in the well.

Ross and Somerset Fields (21). But little data is at hand regarding the Ross gas field on the Amity anticline west of Odell, and the Somerset field on the same anticline to the north of Vanceville. Most of the production comes from the Gantz and Fifth sands.

Linden Gas Pool (30). This is a Fifth sand pool extending along the bottom of the Nineveh syncline west of Linden. The occurrence of gas pools in the bottom of synclines is unusual and as yet has not been satisfactorily explained.

BURGETTSTOWN QUADRANGLE.

The Burgettstown quadrangle lies south of the Beaver and west of the Carnegie quadrangles.

Field work for an oil and gas bulletin on this quadrangle was done by Mr. W. T. Griswold in 1904 in connection with the making of a topographic map of that area. This material was combined with similar data on the Steubenville and Claysville quadrangles, and published in 1907 by the U. S. Geological Survey as Bulletin No. 318.

Previous to this, Mr. Griswold had evolved some new methods of working out the structure of the oil sands, which he had used very successfully in similar work on the Cadiz (Ohio), and the Steubenville (Ohio, West Virginia and Pennsylvania) quadrangles. By this method the elevations above sea level of the mouths of a great number of deep wells were secured with a spirit level. In the course of this level work elevations were also secured on outcropping coal and limestone beds, and the intervals between these beds carefully worked out. With this data in hand it was, therefore, possible to make a very accurate structural map not only of an outcropping bed but also of some deeply buried oil sand. In the Burgettstown quadrangle contours of the structural map of the outcropping beds were drawn on the base of the Pittsburg coal, and those for the oil-bearing bed on the top of the Hundred-foot sand.

Structure. Definite structural features are absent on the Burgettstown quadrangle. The rocks have a general dip to the southeast, which is obscured by an irregular wrinkling of the whole surface into pitching anticlinal domes and canoe-shaped basins having no regular trend. The West Middletown syncline, which crosses the quadrangle from north to south, is the dominant structural feature. Three important oil pools, and as many large gas pools, have been developed within the quadrangle.

Murdocksville-Florence Oil Field (41, 42, 43). This field was discovered in 1888, and was still in course of development in 1904, though most of the producing area had been brought in years before. This field lies along the western flank of the West Middletown syncline for seven miles, with a maximum width of three miles. Developments were begun in the northern portion near Murdocksville and the extension gradually grew southward. In 1904 the Florence pool at the extreme southern end of the producing area was still receiving some attention. It is now entirely developed.

This has been a very productive field in the Hundred-foot sand, which here appears to contain little or no salt water.

Burgettstown-Cross Creek Field (38). This field lies along the sides and across the western end of the Cross creek basin, four miles south of Burgettstown. The Hundred-foot sand produces most of oil, though some is found in the Thirty-foot sand, which is about 100 feet below the Hundred-foot. The wells in this field are usually small, though some good wells are reported. The Hundred-foot sand here is closer and harder than it is usually found to be where it carries oil. The fact that this pool lies squarely across the bottom of the deepest basin on the quadrangle seems to verify the statement that the sand does not carry salt water in this vicinity. This pool was in course of development in 1904.

McDonald Pool (36). A portion of this great pool lies along the eastern edge of the quadrangle from Midway southward. It is discussed as a whole under the Carnegie quadrangle (p. 294).

Hickory-Buffalo Gas Field (35). This field occupies the crest and flanks of the Westland dome, the highest point of which is in the vicinity of Westland, near the southeast corner of the quadrangle. This is the culminating point of the Washington and Claysville anticlines of the Claysville quadrangle. This is an ideal structural feature for gas, and it has produced some of the greatest wells in the State.

The first well drilled in this field and also the first large gas well drilled in Washington county, was completed in 1882 on the H. McGuigan farm, 2½ miles southwest of Hickory, on the southwest slope of the dome. This well furnished an immense flow of gas from the Hundred-foot sand and is considered one of the greatest gas wells ever discovered. Subsequent drilling has proven that this field covers almost the entire area of the dome and includes the Buffalo gas field of the Claysville quadrangle and considerable areas in the Amity and Carnegie quadrangles. Almost all the gas sands from the Salt sand to the Fifth are found to be productive in one or more places on this dome. It has been one of the great gas fields from which Pittsburg has drawn so liberally in the last twenty years. No data is at hand regarding closed pressures in the different producing sands.

Eldersville Gas Pool (39). This pool is situated on the southern nose of an anticline in Jefferson township southeast of Eldersville. It has produced a large quantity of gas from the Hundred-foot sand. Some development was going on in this field in 1904, and the field, as a whole, is comparatively young.

Candor Gas Pool (37). This pool covers several square miles on the crest and eastern and southern flanks of the Candor dome, which is situated about three miles northwest of Midway. Most of the gas is found in the Hundred-foot sand, at approximately the same level as that of the Murdocksville oil pool further to the northwest.

CLAYSVILLE QUADRANGLE.

The Claysville quadrangle lies south of the Burgettstown, west of the Amity, and north of the Rogersville quadrangles. Data for an oil and gas bulletin of this quadrangle was collected by the writer in 1905, at which time he was also engaged in making a topographic map of the area. The bulletin was combined with similar ones of the Burgettstown and Steubenville quadrangles, previously described, and published by the U. S. Geological Survey in 1907 as Bulletin No. 318.

The field work for this bulletin was conducted similarly to that described for the Burgettstown quadrangle, and resulted in the collection of a mass of reliable data, from which it is believed much better results were obtained than could have been possible by the use of the aneroid barometer and hand level in securing vertical control. This data justified the use of 10-foot contours in depicting the structure of both the Upper Washington limestone, which outcrops on this area, and the Gordon sand, which lies from 1,050 to 1,850 feet below sea level.

Structure. The structure of the rocks as revealed by these contours has somewhat the appearance of that described for the Burgettstown, though the northeast-southwest trend of the folds is more distinct.

Washington-Taylorstown Oil Fields (26). This is the one great oil-producing area in the Claysville quadrangle. As previously noted in describing the Amity quadrangle, this great oil belt extends from about six miles northeast of Washington unbroken to within half a mile of the town of Claysville, a distance of about fifteen miles. This field is made up of several overlapping pools in different sands. On the Amity quadrangle the production comes principally from the Gantz and Fifty-foot sands. At Washington, on the eastern border of the Claysville quadrangle, oil in the Gordon sand overlaps that in the Gantz. Westward to Claysville the Gordon is productive in a broad belt encircling the northern side of the Finney syncline. A short distance west of Washington, both the Fourth and Fifth sands become oil-bearing, which extends to the vicinity of Taylorstown, and southward along the bottom and eastern side of the Finney syncline to the southern limits of the field. Along this southern extension the Gordon Stray is also oil-bearing in a number of places.

In this field all the producing sands carry more or less salt water, with the exception of the Gordon Stray and Thirty-foot sands. This water had apparently reached a state of equlibrium in the Gordon, Fourth and Fifth sands. In the Gordon sand the water line lies well up the side of the Finney syncline and at a very definite level. The oil pool lies directly above and in contact with the water.

The water in the Fourth is much less than that in the Gordon and Fifth. It is found only in shallow basins along the trough of the Finney syncline, and where found, the oil is situated similar to that of the Gordon. The Fifth sand carries more water than the Fourth and less than the Gordon, but the oil bears the same relationship to it as described for the others.

We have here three examples in the same field of the evident close relationship of accumulations of oil to salt water. Examining the phenomenon further, we find that the Gordon Stray and the Thirty-foot sands, which overlie the Gordon, carry little or no water, and still higher, the Gantz and Fifty-foot sands produce both oil and water, in which the relationship of oil to water does not appear to conform to any marked extent to the structure. Strange to say, the amount of water in the Gantz and Fifty-foot is less than in the Gordon, and is very irregularly distributed throughout the beds.

The real problem in this field is to account for this peculiar distribution of salt water in the oil sands, and to explain its source.

In April, 1885, the original Gordon well was drilled in West Washington, in which the oil-bearing bed which is equivalent to the Third sand of Butler and Armstrong counties, was called the Gordon sand. From this time the development of the different pools in this pool was rapid, statements in regard to which have previously been made in this paper, (p. 279), the latest extension is that in the Gordon Stray and Fifth sands at the extreme southern edge of the field, where some drilling was going on at the time the field work for this paper was done in 1905. There is a possibility that this field will be further extended to the southwest and make a more or less complete connection with the Dague pool, on the eastern flank of the Finney syncline in the south central portion of the quadrangle.

The Dague Pool (24). This pool is located in East Finley township, Washington county, six miles south of Claysville. The first well in this pool came in on the Dague farm in 1906. It flowed 400 barrels per day from the Fourth sand. At the time of the writer's visit in September, 1907, there were two producing wells in this sand, and several others were stopped for gas in the Big Injun. The Dague well was still flowing freely, but its capacity was not determined. From the structural location of this pool and the staying qualities of the Dague well, this pool offers good inducements for future prospecting

Point Lookout Pool (25). This is a small pool of three wells in the Fifth sand, situated about five miles south of Washington. It has been pretty well encircled with dry holes, so that the chance of an extension to it is small. The best point for a test in this locality is one-half mile southeast of Point Lookout.

Buffalo Gas Field (29). Within this field is included all the gas territory on the Westland dome north of the Washington-Taylorsville oil field.

This dome is the same structural feature that has produced so much gas in the southeastern portion of the Burgettstown, the southwestern corner of the Carnegie, and the northwestern part of the Amity quadrangles. Within the Claysville quadrangle it has furnished gas in immense quantities from the Big Injun, Salt, Gantz, Fifty-foot, Gordon, Fourth and Fifth sands. The Gordon sand probably leads in the amount produced.

Lagonda Gas Field (27). This field lies to the southwest of Washington on the Washington anticline. This field has produced a large quantity of gas from the Salt, Gantz, Fifty-foot, Gordon and Fifth. A great many of the wells are still connected to the pipe line.

In East and West Finley townships, in the southwest quarter of the quadrangle, a number of scattered wells produce gas from the Big Injun and Salt sands. Among these are the wells mentioned above in the Dague pool.

Mehaffey Gas Pool (28). This pool is situated about three miles northwest of Claysville on an anticlinal nose which juts out to the west from the Claysville anticline. No wells had been drilled in this pool at the time the structure was mapped in 1905, the first well being put down on the Mehaffey farm in 1906, getting a large flow of gas in the Gordon sand. At the time of the writer's visit to this field in September, 1907, there were fifteen or more wells, all of which got their gas in this sand. This pool is situated close to the northwest limit of the Gordon sand, which at this point is from 7 to 10 feet thick.

These wells show a closed pressure of about 900 pounds, which is probably about the maximum pressure for the Gordon sand in Washington county. The gas wells along the crest of the Claysville anticline, a mile and a half to the east of the Mehaffey pool originally produced in this sand at a closed pressure of about 900 pounds, but are now so nearly exhausted that the closed pressure is not more than 150 pounds. A well on the Liggett farm drilled several years ago about half way between these two areas, is said to have had a fair Gordon sand, but little or no gas. From these facts, it seems quite probable that the Gordon pay is a lentil that does not connect these two pools, and that a barren streak lies between them. For this reason it looks as if this pool does not extend east of Buck run, unless it crosses north of the Chapman dry hole near Donley.

If the Gordon carries salt water in the syncline north of the Mehaffey pool at the mouth of Buck run, and the sand is good, indications point toward the discovery of oil in this sand to the north and northeast of the present developments. If oil is found here it will be found to lie in an east and west direction, and developments should not venture further northward after salt water is encountered.

CLARION QUADRANGLE.

The Clarion quadrangle lies north of the Rural Valley.

Field work for an oil and gas bulletin of this quadrangle was commenced in 1905 by Mr. W. T. Griswold, in connection with the making of a topographic map of the quadrangle. Circumstances prevented the completion of this work in 1905. In 1906, Mr. E. F. Lines secured additional data in connection with geologic work for a folio, and special papers on the coals and clays. In July, 1907, the writer spent three weeks in a hurried examination of the principal oil and gas pools of the quadrangle. The oil and gas bulletin of the quadrangle is now being prepared.

Structure. The structure of the rocks on this quadrangle is shown by 25-foot contour lines drawn on the Lower Kittanning coal, it being found that not enough data is available to justify the attempt to depict the structure in detail on one of the producing sands.

In the eastern part of the quadrangle the anticlines and synclines are clearly defined, but in the western portion the rocks are less disturbed, the structural features having no general trend.

The first producing oil wells within this area date back to the time of the Oil City excitement in the 60's. At that time some venturesome oil men from Venango county drilled a well on the north bank of Clarion river, about a mile west of Piney, Beaver township. Some oil was found in this well which led to the drilling of several others in the same vicinity, all of which gave a total production of several hundred barrels. This was shipped down the river on barges to Pittsburg. The venture does not appear to have turned out profitably, however, as the wells soon filled with salt water and were abandoned. Other wells were drilled at various places in the county between 1861 and 1870.

Elk City Oil Pool (105). A portion of this pool is included within the northwest corner of the quadrangle. This pool was developed in 1875-76, at which time hundreds of wel's were drilled in it. The best wells ranged from 100 to 300 barrels from the Third and Fourth sands. These sands run together in this field and are probably equivalent to the Venango Third sand. Many of these wells are still pumping, the average production being less than a barrel per day.

Some salt water is found in the lower portion of the sand in this pool, and those wells holding up best in oil are also, as a rule, the ones that pump the most water. Usually the production of oil ceases in a well when the water is exhausted.

Clarion Oil Pool (106). This pool is located in and to the south of the town of Clarion. The first well was brought in on the Normal School property in January, 1888. This well started at 20 barrels per hour, but soon declined to 30 barrels per day. The pool was rapidly developed from that date. On October 24, 1888, about thirty wells were in, with a maximum daily production of 2,800 barrels. The wells in this field were very eratic, and, as a rule, short-lived, though a number of the first wells drilled are still producing. The pool has been gradually developed southward, and at present new wells are being brought in on this extension. The oil comes from the Third and Fourth sands, which carries some salt water.

Miola Oil and Gas Pool (117). This pool extends from the river north of Clarion to the northern border of the quadrangle at Miola. This field was partly developed as a gas pool producing from the Third sand, which is here separated from the Fourth sand by from 2 to 20 feet of shale. In December, 1906, a well on the Isaac Imhoff farm, which had been producing gas for eight years, was drilled 20 feet deeper, through two feet of shale into the Fourth sand. It began flowing oil at the rate of 80 barrels per day. The whole field was quickly converted into an oil pool by deepening the wells. At the time of the writer's visit in July, 1907, there were over fifty oil wells in the field and several drilling. The present production is not known.

Manor Oil Pools (108). This pool is located in the southwestern part of Paint township, on the Kizer, Hepinger and Grace farms. It was opend up about 1893-94, with 11 producing wells in the Third and Fourth sands. The best well in the pool was the S. E. Kizer No. 2, which produced about 60 barrels per day for the first year. The pool covered about 100 acres, but is now producing only a few barrels a day from three or four wells. This pool has been thoroughly tested, and there is little chance of finding extensions to it.

Oil in small quantities has been found at several other points within the quadrangle, but no pools worth noting have yet been discovered.

The Elk City pool lies on the west side and at the head of a shallow, canoe-shaped synclinal trough, which deepens along its axis to the southeast to where it is lost in the greater depression of the Reidsburg syncline in the vicinity of that village.

The Clarion and Miola pools lie along the crest of a secondary arch, between the above-mentioned synclinal trough and the Reidsburg syncline, north of the junction of these synclines.

The Clarion and Elk City pools lie at about the same level in the Third and Fourth sands. Structurally, the Miola pool is about 100 feet higher.

Gas Fields. No very large pools of gas have yet been developed on the Clarion quadrangle. The whole area is dotted, however, with small fields of from one or two to thirty wells each.

The majority of the wells appear to be good average producers, with here and there one that makes several million cubic feet per day.

The gas-bearing sands named according to the amount of production in descending order are, Murrysville, Speechley, Fourth, Bradford, Hundred-foot, Third, Thirty-foot, Fifth, First, Second and Tiona.

No attempt will be made in this paper to describe these pools in detail. The principal producing areas lie along the crest or flanks of the Kellersburg anticline and the lower anticline lying west of the Brady's Bend syncline. Some good wells have been found in the Murrysville and Speechley sands well down on the flanks in this syncline, and some gas in the Thirty-foot sand in the bottom of this trough. The field in and to the northeast of Sligo also lies well down in a shallow syncline, which pitches rapidly to the west.

Pressure in Gas Wells. But few detailed records of the production of gas wells within the Clarion quadrangle have been kept by the producers, and in a number of these that the writer has examined the gas comes from more than one sand, so that the pressure and amount of production from each sand could not be determined. Enough data was collected, however, to admit of a general statement regarding the closed pressure of gas in the different sands.

Beginning at the top of the geologic column, the First and Second sands have a closed pressure from less than 100 to about 300 pounds, the average being between 150 and 200. The Murrysville sand usually has a closed pressure of from 150 to 190 pounds. In one well it is recorded as 250 pounds. No initial closed pressures of gas in the Hundred-foot are at hand, but it is thought not to exceed 400 pounds. The initial pressure in the Third sand ranges from 180 to 275 pounds, most of those recorded being near 180 pounds. The maximum pressure recorded for the Fourth sand is 500 pounds. The Speechley sand generally carries the highest closed pressure, which ranges from 600 to 900 pounds. One record shows a closed pressure in this sand of only 150 pounds, but this may be a mistake, or it may come from an exhausted area. The recorded pressures in the radford sand range from 330 to 425 pounds, though it is reported that in this sand a pressure of 1,500 pounds was registered in one well, but this report could not be verified. No closed pressures are at hand for the Thirty-foot, Fifth and Tiona sands, though in the latter it is reported to be very great.

On the whole, this question of pressure and capacity of gas wells offers a very attractive field for investigations, and from the factors involved it seems possible that detailed studies along this line might give results of very great value to the producer.

SEWICKLEY QUADRANGLE.

The Sewickley quadrangle lies east of the Beaver, northeast of the Burgettstown, and north of the Carnegie quadrangles.

Field work was done by the writer in 1906 for a folio and an oil and gas bulletin of this quadrangle. The bulletin, which should have been published in 1907, was delayed for the publication of the topographic map of this quadrangle, which is used as a base for the geologic map. In 1907 three weeks were spent in the quadrangle collecting additional data for both publications. The manuscript for the oil and gas bulletin is now (June 16, 1908) nearing completion. The folio will not be ready for publication this year.

Structure. The field work for the oil and gas bulletin was conducted along similar lines to that already described for the Claysville and Burgettstown quadrangles. The vertical control for the structural map was secured by spirit level lines to hundreds of wells, and coal and limestone outcrops.

On the maps which will accompany this bulletin the structure of both the outcropping bed and the oil sand will be represented by 10-foot contours on the Ames limestone and Hundred-foot sand, respectively. These contours show that three distinct anticlines and an equal number of synclines cross the quadrangle with sinuous north-south trends. The axes of all these folds pitch to the south, the synclines having a tendency to flatten out going northward.

The Sewickley quadrangle embraces some of the most prolific oil-bearing territory of southwestern Pennsylvania. This production comes chiefly from the Hundred-foot, Gordon, Snee, Boulder, Fourth, Thirty-foot and Fifth sands, named in the decreasing order of production. There are at least sixty distinct oil pools on this quadrangle, and nearly that number of gas pools. Owing to their number, these pools will be grouped and discussed by sands.

Hundred-foot Sand. More than thirty pools of oil have been developed in the Hundred-foot sand in this area. The most important of these are, the Brush Creek (70), Crows Run (75), Cookston (73), Legionville-Economy (52), Leetsdale (51), Perryville (62), Ramsey (84), Ingomar (68), Wexford (69), Mars (79), Crider (76), Garvin (82), Callery

(79), and Evans City (80) pools. Nine-tenths of the productive territory in this sand lies along or near the axis of the anticlines.

The oil is everywhere accompanied by more or less salt water. From this fact, however, it should not be inferred that the whole bed is saturated. On the contrary, this is found to not be true. There are several considerable areas within the quadrangle in which the sand appears to be of inferior quality as regards porosity, and in which neither oil, gas nor water have been found.* Data on this point is difficult to obtain. The wildcat wells that tested a large part of the unproductive portion have been drilled for several years, and their owners did not, as a rule, consider the records of such holes worth preserving. Most of the data has been secured by personal interviews with the drillers and contractors who drilled the wells. This is a slow and expensive way to get facts, and since much of it is given from memory it is not always reliable. However, it is believed that enough has been learned to justify the statement that over the greater part of the quadrangle the Hundred-foot sand carries a perceptible amount of salt water. The areas in which no salt water is found in the Hundred-foot are no more numerous on the anticlines than in the synclines, but apparently are irregular shaped patches which may occur at any structural point.

The relationship of oil and water in this sand is here quite different from that of the Gordon, Fourth and Fifth sands in the Claysville quadrangle (p. 283). Here the oil and water evidently come out of the sand together. This proportion of oil to water does not seem to be affected either by the porosity of the pay sand or by the structural location. A pool located 200 feet higher structurally than another in the same sand having apparently the same porosity, and located on the same anticline, may pump more water per barrel of oil than the lower pool. Strange to say, in some cases the lower pool becomes exhausted of both oil and water before the higher one. In all cases, the initial production of oil and water in a well is the maximum production of both. At first the decrease of oil in a well is usually more rapid than that of the water. After a certain stage is reached the ratio of oil to water apparently remains constant. The wells usually make from one-half to twenty times as much water as oil. With a given production of oil the well making the most water is the better well, and will have a longer life, for when the water is exhausted no more oil is produced. Many wells in a pool continue to pump water and oil for years after adjoining wells of equal initial capacity and elevation have been exhausted. The first wells in a pool frequently flow with the escape of considerable gas. As development proceeds less and less gas is encountered, until many wells which fill up from 500 to 1,500 feet with oil and water show but little gas. When these wells are pumped for six months or a year and then left to stand, they never fill up to the initial level. Frequently at the end of a month a well will show when pumped off only four or five times its regular daily capacity. The amount of head which a well will thus accumulate apparently bears no structural relation to similar heads in other wells in the same pool. These facts are difficult to explain, but most of the evidence seems to point toward the conclusion that this water comes from the Butler gas or Thirty-foot sand, which overlies the Hundred-foot from thirty to eighty feet. This sand carries salt water under a considerable head throughout the quadrangle, and the saturated areas in the Hundred-foot may be situated at points where this water has penetrated the shales in sufficient quantities to establish pools having varying hydraulic* (not hydrostatic) pressures.

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*There may not be universal agreement with Mr. Munn's implied definition of non-saturation G. H. A.

Many of the wells in the Hundred-foot sand pools come in at several hundred barrels per day. The wells, as a rule, are good stayers and have proven very profitable.

Gas Pools in the Hundred-foot Sand. This sand has not been as prolific in the production of gas as of oil. No large pools have been found in the quadrangle. Every oil pool, however, has a larger or smaller gas pools associated with it. The larger of these pools lie at the north ends of the Economy and the Crows Run oil pools, and another is situated a mile north of Lovi (76). No salt water was found with the gas when the wells were fresh, but in some of the wells small quantities of water have since appeared.

Gordon, or Third Sand. This sand has been the principal producer in the Moon (49), Coraopolis (50), Mt. Nebo (60), Sandle (63), and Wildwood pools (65), and has also furnished a considerable portion of that from the Glenfield (61), and Neville Island pools (48). All these pools are situated southeast of a line drawn from the southwest corner of the quadrangle to a point midway along its eastern border. Northwestward from this line the Gordon as recognizable horizon disappears. In the Moon and Coraopolis pools this sand carries salt water along the southern margin; in the other pools it shows no water. Unlike the Gordon pools on the Claysville quadrangle, the ones that carry water here do not lie at a certain level along the sides of the anticline. The tendency of the water to invade and drown out partially exhausted wells along its margin is, however, similar in both pools. The action of salt water in this sand is directly opposite to that of water in the Hundred-foot sand. In the Gordon a well that once begins pumping salt water is doomed to sooner or later pump water exclusively. The longest-lived wells in the Gordon are those that produce no water. As a rule, wells in the Gordon sand on this quadrangle have been good producers. The better ones had initial capacities of from one to five hundred barrels per day.

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*The senior author questions the use of "hydraulic."

Gas Pools in the Gordon Sand. No large gas pools occur in this sand within the quadrangle. The largest pool known occupies the eastern flank of a small dome near the southwest corner of the quadrangle and up the slope from the Coraopolis oil pool. Another pool is situated on the top of the anticlinal nose south of the Mt. Nebo oil pool. A number of wells in the Ingomar oil pool make gas from the Gordon sand, the northwest margin of which lies a short distance further north.

Snee, or Blue Monday, Sand. This sand is the topmost member of the three sands making up the Gordon group in this region. The second sand of this group is the Boulder, or Gordon Stray, and the lowest is the Gordon, or Third sand, described above.

The Snee sand was first discovered to be a producer in this quadrangle in a well at Duff City (72), near the center of the quadrangle. Subsequently, a very productive pool of small size was opened up here. Later, a larger pool was opened up in this sand at Criders Corners (76), five miles west of Mars. Several wells in this pool produced more than 100 barrels per day. An extension of this pool to the northeast was found in the Peters pool (78). Several wells along the eastern edge of the Brush Creek pool (71), which is in the Hundred-foot sand, also get oil in the Snee sand. No gas pools of consequence have been found in this sand, though the oil is usually accompanied by more or less gas, and a few scattered wells produce gas entirely. The Snee sand carries little, if any, salt water, notwithstanding the fact that all its oil pools are at or near the crest of the Brush creek anticline.

Boulder, or Gordon Stray, Sand. This sand produces oil from a number of wells in the Peters (78), and Grubbs (58) pools, some of the wells in the latter being of over 100 barrels capacity. The sand also furnishes two small pools of flowing wells on Big Sewickley creek four miles north of Leetsdale, known as the Davis (57), and the Craig pools (72), the total production of which is small.

The only gas pool of any consequence found in this sand occupies the crest of the Wildwood anticline, north of Dixmont (62). This pool contains twenty or more good wells. No salt water is reported in this sand. The Peters and Grubbs oil pools are located squarely on the crest of the Brush creek anticline. The Davis and Craig pools, which carry sufficient gas to flow the wells, are located well down on the eastern slope of the Crow's run anticline, the Craig pool being near the trough of the Sewickley syncline. This arrangement is just the reverse from that which we would expect from the anticlinal theory.

Fourth Sand. The Fourth sand is present under the southern and eastern third of the quadrangle. Within this area it has furnished a large number of widely scattered gas wells of more than ordinary capacity, and much of the oil which has come from the Glenfield (60), Neville Island (47), and Bellevue (61), oil pools. The largest accumulations of gas in this sand are the Carnot-Leetsdale (67), and the Keown (66) pools. These gas pools are the largest on the quadrangle. The Fourth sand probably furnishes more gas than all the other sands combined. The wells, though not phenomenal in capacity, hold up well. The closed pressure varies from less than 300 to about 600 pounds, the maximum minute pressure being above 200 pounds. Little or no water occurs in this sand.

Thirty-foot Sand. This is the first producing sand below the Hundred foot. In this quadrangle oil is found in it in a number of wells in the Duff City field (72), in two wells west of Wexford, and four or five wells in the western end of the Sandle field (64). No water is mentioned in any of these wells. The Duff City pool is on the crest of an anticline; the others are on the slopes of anticlines. The total production from this sand has not been great, though some of the wells were of considerable size.

Fifth Sand. The Fifth sand underlies only the southeast quarter of this quadrangle. It produces some oil on Neville Island and in the vicinity of Avalon and Bellevue. Gas in this sand is confined to scattered wells in the vicinity of Mt. Nebo and Perryville. The total production of both oil and gas from this sand has been small.

CARNEGIE QUADRANGLE.

The Carnegie quadrangle is north of the Amity and east of the Burgettstown quadrangles. In 1907 field work for a folio was done by G. C. Martin and F. B. Peck, and that for an oil and gas bulletin, by the writer. Both of these papers are now in course of preparation.

The field work for the bulletin was carried on after the plan already described for the Sewickley and Burgettstown quadrangles. At the time this work was done it was thought that this area offered the opportunity for the making of a very detailed map of the oil sands, and for this reason spirit-level lines were run to a large per cent. of the wells. Later, it was found that the records of most of these wells were not preserved so as to be available. This will materially affect the accuracy of the map. This data is not at present in shape for more than a general outline.

McDonald Oil Field (36). This is the greatest oil field in southwestern Pennsylvania and one of the largest in the Appalachian region. The first wells in this field were drilled in the spring of 1891. In November of the same year the production from this field was more than 75,000 barrels per day. A single well, the Mevey gusher, made about 100,000 barrels in eleven days. The best run from a single well in 24 hours is said to have been about 18,000 barrels. Many wells in this field started off at more than 100 barrels per hour, and some of these are still pumping. One well is said to have to its credit a total of production of as much as 2,000,000 barrels.

This enormous volume of oil comes principally from the Fifth sand, though the Gordon also is a good producer. Some smaller pools in the McDonald field are in the Fourth, Gordon Stray, Thirty-foot, Gantz and Fifty-foot sands, but this field will go down in history as the greatest Fifth sand pool ever discovered.

The phenomenal feature of this great field is the thinness of the producing sands in comparison to the amount of oil produced. In the Mathews well, which was one of the very large wells, the Gordon sand is only 28 feet thick. That of the Fifth is not given in the record, but at the time of its greatest flow the hole extended only about 10 feet into this sand. Judging from the thickness of this sand in nearby wells, it is probably not over 30 feet. This is one of the wells that is said to have produced more than 2,000,000 barrels of oil, and after 16 years it is still making about fifteen barrels per day, notwithstanding the fact that it is encircled by other good wells, some of which are not over 400 feet distance. Both the Gordon and Fifth sands show a little water in places throughout the field, but the percentage of wells pumping some water is small.

The structure of the sand in this pool has not yet been worked out in detail, but that for the Pittsburg coal shows that this pool lies on the west flank of the Nineveh syncline. Its northwest boundary is governed by the limit of the Fifth sand in that direction, which disappears entirely within a mile of the producing area. The Fifth sand pool in the McDonald field may, therefore, be said to lie along the irregular slope of an anticline at the upper edge of the sand, with little or no water showing in the sand below the oil. What is said of the Fifth is also true of all the other producing sands, except that they are not limited in extent toward the northwest. The Hundred-foot is the only oil-bearing sand of this field that carries much salt water. In it the oil and water bear the same general relation to each other that were mentioned in the discussion of this sand on the Claysville and Sewickley quadrangles. Southeastward from the McDonald pool the number of wells reporting salt water in this sand grows less and less, notwithstanding the fact that the general dip of the rocks is in that direction. In the McMurry pool (31), in the southeast quarter of the quadrangle, the Fifty-foot sand, which is the lower member of the Hundred-foot, furnishes most of the oil and water.

What has been said of the oil sands in the McDonald field might be repeated for the chain of pools lying to the northeast and to the south of it, with only slight variations regarding amount of production, the changes in producing sands, and minor differences in structural location of pools. Geologically, the McDonald field might easily include all of these more or less distinct pools. A more detailed discussion of these pools is reserved for the oil and gas bulletins of this quadrangle.

Producing areas less closely associated with the McDonald field are the Imperial (43), McCormick (48), and Heidelburg pools (33), in the Thirty-foot sand, and a small extension of the Moon pool in the extreme northwest corner of the quadrangle, which gets its oil in the Gordon sand. Of these pools, the first two are located higher, structurally, than the McDonald field, and the third, which is also in the Thirty-foot, lies almost squarely in the trough of the Nineveh syncline. No water is reported in this sand in any of these pools. The sand in the Moon pool is higher structurally than it is in the McDonald pool, but it produces more salt water, and numerous wells between these areas report little or no water in this sand. Attention is called to these facts to show that the enigmatic processes by which these pools of oil have been accumulated are still unexplained, and that the anticlinal theory must be subjected to some drastic fundamental revisions before it can be made to satisfy the apparently conflicting data brought to light by the incessant work of the drill.

The principal gas pools within this area are situated in the four corners of the quadrangle. In the northeast corner considerable gas has been found in Pittsburg and to the north and west of the city. The northwest corner furnishes Big Injun, Hundred-foot and Fourth sand gas to the north of Imperial. The Westland dome, which juts over into the southwest corner of the quadrangle, has furnished an immense amount of gas from several of the sands. In the southeast corner the Big Injun, Salt sand, Gantz, Gordon and Fifth have all produced considerable quantities of gas. In addition, the Thirty-foot and Fifty-foot sands have several good gas wells near Sodom (33), and Bridgeville (32), and throughout the McDonald field each of the oil sands have furnished larger or smaller pools of gas. The structural position of these pools, while in the main occupying the tops of domes and anticlines, shows many small local deviations from this rule.

A List of the Producing Fields and Other Data.

Number.	Name of Field.	Sands Producing Oil.	Sands Producing Gas.	Location of Pools by Quadrangles.	Page reference to text.
1.	Broad Tree,	Big Injun, Nineveh, Gordon,	Big Injun and Salt,	S. W. corner of map,	
2.	New Freeport,	Nineveh and Gordon,	Salt, Gordon, Fourth, Fifth,	S. W. corner of map,	
3.	Aleppo,	Gordon, Fourth,	Fifth, Nineveh,	Rogersville,	
4.	Lantz,	Fifth,		Rogersville,	
5.	Bristoria,	Nineveh,	Nineveh, Gordon Stray, Gordon,	Rogersville,	
6.	Grays Fork,	Nineveh,		Rogersville,	
7.	Nineveh,	Nineveh and Gordon Stray,		Rogersville,	
8.	Waynesburg,		Bayard, Fifth, Gordon, Gantz, Big Injun.	Waynesburg,	
9.	Mt. Morris,	Big Injun,		Waynesburg,	
10.	Garrison,	Dunkard,		Waynesburg,	
11.	Whitely Creek,	Dunkard and Big Injun,		Masontown,	
12.	Blackshire,	Big Injun,		Masontown,	
13.	New Geneva,		Big Injun and Fifty-foot,	Masontown,	
14.	Masontown,		Gantz and Big Injun,	Masontown,	
15.	Fayette,		Big Injun,	Masontown,	
16.	Hadenville,		Gantz, Fifty-foot, Big Injun,	Masontown,	
17.	Zollarsville,	Hundred-foot,	Elizabeth, Bayard, Fifth, Fourth, Gantz, Fifty-foot, Big Injun.	Amity,	
18.	Centerville,		Fifty-foot and Elizabeth,	Brownsville,	
19.	Bellevernon,		Big Injun, Gantz, Fifty-foot,	Brownsville,	
20.	Forward,		Big Injun, Gantz, Fifty-foot, Gordon, Sixth or Elizabeth.	Brownsville,	
21.	Ross and Somerset,		Gantz, Fifty-foot,	Amity,	
22.	Amity,		Salt, Big Injun, Gantz, Fifty-foot, Gordon, Fourth and Fifth.	Amity,	
23.	Fonner,	Gantz and Fifty-foot,		Amity,	
24.	Dague,	Fourth,	Big Injun,	Claysville,	
25.	Point Lookout,	Fifth,		Claysville,	
26.	Washington-Taylorstown,	Gordon, Fourth, Fifth, Gantz, Fifty-foot, Thirty-foot, Gordon Stray and Big Injun.	Gordon, Fourth, Fifth, Gantz, Fifty-foot, Thirty-foot, Gordon Stray, Big Injun.	Claysville and Amity,	
27.	Lagonda,		Salt, Gantz, Fifty-foot, Gordon, Fifth,	Claysville,	
28.	Mehaffey,		Gordon,	Claysville,	
29.	Buffalo,		Salt, Big Injun, Gantz, Fifty-foot, Gordon, Fifth.	Claysville,	
30.	Linden,		Fifth,	Amity,	
31.	McMurry,	Fifty-foot and Gantz,	Gantz, Gordan, Fifth,	Carnegie,	
32.	Bridgeville,		Thirty-foot,	Carnegie,	
33.	Sodom,		Thirty-foot, Fourth and Fifth,	Carnegie,	

34.	Heidelburg,	Thirty-foot,		Carnegie,	
35.	Cannonsburg,	Gordon, Thirty-foot, Fifth and Fifty-foot.	Thirty-foot, Gantz, Fifty-foot, etc.,	Carnegie,	
36.	Hickory,		All sands from Salt to Fifth, inclusive,	Burgettstown,	
37.	McDonald,	Fifth, Fourth, Gordon, Thirty-foot, Gordon Stray, Gantz, Fifty-foot, etc.	Fifth, Fourth, Gordon, Thirty-foot, Gordon Stray, Gantz, Fifty-foot, etc.	Carnegie,	
38.	Candor,		Gantz and Fifty-foot,	Burgettstown,	
39.	Burgettstown,	Gantz and Fifty-foot (Hundred-foot),	Gantz and Fifty-foot (Hundred-foot),	Burgettstown,	
40.	Eldersville,		Hundred-foot,	Burgettstown,	
41.	Florence,	Hundred-foot,		Burgettstown,	
42.	Five Point,	Hundred-foot,	Hundred-foot,	Burgettstown,	
43.	Murdocksville,	Hundred-foot,	Hundred-foot,	Burgettstown,	
44.	Imperial,	Thirty-foot,	Hundred-foot, Thirty-foot,	Burgettstown,	
45.	McCurdy,	Fifth and Gordon,	?	Carnegie,	
46.	Moon Run,	Fifth, Fourth, Gordon,	Fifth, Thirty-foot (?),	Carnegie,	
47.	Crafton,	Gordon,	Fourth,	Carnegie,	
48.	Neville Island,	Gordon, Fourth, Fifth,	Fourth, Fifth,	Carnegie and Sewickley,	
49.	McCormick,	Thirty-foot,	Gordon (?),	Carnegie,	
50.	Moon,	Gordon,	?	Carnegie, Burgettstown and Sewickley.	
51.	Coraopolis,	Gordon,	Fourth,	Sewickley,	
52.	Leetsdale,	Hundred-foot,	Fourth, Gordon,	Sewickley,	
53.	Legionville-Economy,	Hundred-foot,	Hundred-foot,	Sewickley,	
54.	Shannopin,	Hundred-foot,	Hundred-foot,	Beaver and Sewickley,	
55.	New Sheffield,		Hundred-foot,	Beaver and Sewickley,	
56.	Hookstown,	Berea (?),		Beaver,	
57.	Smiths Ferry,	Salt, Big Injun, Berea (?),		Beaver,	
58.	Davis,	Boulder and Hundred-foot,	Hundred-foot,	Sewickley,	
59.	Grubbs,	Boulder and Hundred-foot,	Fourth,	Sewickley,	
60.	Mt. Nebo,	Gordon,	Fourth and Fifth,	Sewickley,	
61.	Glenfield,	Gordon, Fourth,	Fourth,	Sewickley,	
62.	Dixmont,		Boulder,	Sewickley,	
63.	Perryville,	Hundred-foot and Gordon,	Gordon and Fourth,	Sewickley,	
64.	Sandle,	Gordon and Hundred-foot,	Fourth (?),	Sewickley,	
65.	Wildwood,	Gordon,	?	Sewickley,	
66.	Bellevue,	Gordon, Fourth and Fifth,	Fourth, Fifth,	Sewickley,	
67.	Keown,		Gordon and Fourth,	Sewickley,	
68.	Carnot-Leetsdale,		Gordon and Fourth,	Sewickley,	
69.	Ingomar,	Hundred-foot and Gordon,	Gordon,	Sewickley,	
70.	Wexford,	Hundred-foot,	Gordon (?),	Sewickley,	
71.	Brush Creek,	Hundred-foot, Snee, Boulder,	?	Sewickley,	
72.	Duff City,	Snee, Thirty-foot, Boulder (?), Hundred-foot.	?	Sewickley,	
73.	Craig,	Boulder,	Boulder,	Sewickley,	
74.	Cookston,	Hundred-foot,	?	Sewickley,	
75.	Crows Run,	Hundred-foot,	Hundred-foot,	Sewickley,	
76.	Lovi,		Hundred-foot,	Sewickley,	
77.	Criders,	Snee and Hundred-foot,	?	Sewickley,	
78.	Peters,	Boulder, Snee, Hundred-foot,	?	Sewickley,	
79.	Mars,	Hundred-foot,	?	Sewickley,	
80.	Callery,	Hundred-foot,	Hundred-foot,	Sewickley,	
81.	Evans City,	Hundred-foot,	Hundred-foot,	Sewickley,	
82.	Ramsey,	Hundred-foot,	Hundred-foot,	Sewickley,	
83.	Garvin,	Hundred-foot,	Hundred-foot,	Sewickley,	

A List of the Producing Fields and Other Data.—Continued.

Number.	Name of Field.	Sands Producing Oil.	Sands Producing Gas.	Location of Pools by Quadrangles.	Page reference to text.
84.	Creekside,		Murrysville (?),	Indiana,	
85.	Willetts,		Murrysville,	Indiana and Elders Ridge,	
86.	Plum Run,		Murrysville,	Elders Ridge,	
87.	Girty,		Murrysville,	Elders Ridge,	
88.	Roaring Run,		Murrysville, Hundred-foot,	Elders Ridge,	
89.	Shellhammer,		Hundred-foot, Third, Fifth,	Elders Ridge,	
90.	Rockville,		Murrysville, Third, Fifth,	Elders Ridge,	
91.	Say,		Murrysville, Hundred-foot,	Elders Ridge,	
92.	Bradys Bend,		?	Kittanning,	
93.	Karns City,	Stray, Third and Fourth,		Kittanning,	
94.	Winfield,			Kittanning,	
95.	Glade Run,			Kittanning,	
96.	Limestone Run (Limestone).			Kittanning,	
97.	Madison,			Rural Valley,	
98.	Cowanshannock,			Rural Valley,	
99.	Ford City,			Kittanning,	
100.	Garrett Run,			Rural Valley,	
101.	Atwood,			Rural Valley,	
102.	Mahoning Furnace,			Rural Valley,	
103.	?				
104.	Slate Lick,		Speechley,	Kittanning,	
105.	Elk City,	Third, Fourth,	Speechley (?),	Clarion,	
106.	Clarion,	Third, Fourth,	?	Clarion,	
107.	Miola,	Fourth,	Third,	Clarion,	
108.	Manor,	Third, Fourth,	?	Clarion,	
109.	Bittenbender,		Murrysville, Fourth, Speechley, Hundred-foot.	Clarion,	
110.	Blair,		Murrysville, Hundred-foot, Fourth, Speechley.	Clarion,	
111.	Piolett,		Murrysville, Hundred-foot, Fourth, Speechley.	Clarion,	
112.	Frogtown-Greenville,		Murrysville, Hundred-foot, Bradford, Speechley.	Clarion,	
113.	Piney Grove,		Murrysville, Speechley, Bradford,	Clarion,	
114.	George,		Murrysville (?), Speechley,	Clarion,	
115.	Latrobe,			Latrobe,	

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CONCLUSION.

In summing up it becomes evident that, notwithstanding the fact that a large portion of the producing area of Pennsylvania has been covered by geologic work, it must be admitted that but little progress has been made in solving the enigmatic problem of oil and gas accumulation. The data obtained in this work are so widely scattered, and so general and fragmental in their nature, that when considered separately by quadrangles their correct interpretation by geologists has been extremely difficult. Most of the data obtained in these superficial examinations of oil and gas fields may easily be interpreted to favor the Anticlinal Theory. In cases where facts have appeared to be at variance with this theory they have been too frequently dismissed as unreliable, or else accredited to that bugbear of the oil geologist, imperviousness of strata. In this work no geologist has had an opportunity to collect and arrange sufficient facts regarding oil and gas accumulation to enable him to get a comprehensive grasp of the problem as a whole. Such a study would require a detailed examination of a large number of oil and gas pools and the collection of a great mass of data relative to the geologic conditions that have been found in them. To some extent the work done for oil and gas bulletins is intended to furnish such material, but this method of investigation has been carried over such a small portion of the Appalachian fields to date that any positive conclusions drawn from the facts in hand might have but a local application. In a few instances the teachings of the Anticlinal Theory are apparently so widely at variance with the facts that it might be of value to point those cases out in somewhat more detail.

A glance at the accompanying map will show that most of the enormous gas fields of Pennsylvania lie in the more steeply folded region to the east of the great oil belt, which is in much flatter rocks. The fact that gas occurs in these steeper anticlines shows (a), that the pervious bed has a sufficiently impervious cover for oil; (b), that there must be a source for oil where such a quantity of the lighter form of the paraffin group is present; (c), the gas-bearing bed is apparently of equal porosity to that in the oil fields. According to the Anticlinal Theory, should this region not be especially rich in oil, since in the steep dips gravity would be much more effective in moving the oil?

In most of the area covered by the Venango oil sand group south of Butler county no salt water is found in these sands, and where it is found the amount is very small, and the area of saturation of local extent only, except that in the Gordon sand of the Washington-

Taylorstown field, as prevoiusly mentioned. Going northward from this field the rocks rise. At Cannonsburg the Gordon sand still carries some water in places. Here the Fourth is dry and the Fifth carries little or no water. At Venice the Gordon and Fifth sometimes carry a little water, but the remaining portions are filled with oil. At McDonald both these sands are practically dry, though a little water is sometimes found in a well here and there. Continuing northward at a higher point in the sands, the Moon and Coraopolis oil pools of the Gordon sand show considerable water. At the southern (lower) edge of the Coraopolis in this sand the water has sufficient head to drown out wells that are almost exhausted. The fact that such wells that are drowned show a marked increase in production for a few days before this happens, shows that the water actually creeps up the slope of the sand from below. Yet it should be remembered that the Gordon sand is apparently dry 100 feet lower down and less than three miles distance from the Coraopolis pool. Higher up, this sand seldom, if ever, shows water. At Glenfield the data in hand does not give any clue as to the water conditions in the Gordon, nor is the evidence clear at Mt. Nebo, but from what could be learned, the sand shows no water.

In the Sandle and Wildwood pools the sand shows no water. All the pools mentioned in the Gordon sand are situated along the flanks of an anticline, except the Mt. Nebo field, which is cut across by the Mt. Nebo syncline. The Wildwood pool lies along the eastern crest and slope of the anticline of that name. No Gordon water has been found on the slope of the sand below this pool, so far as the writer's inquiries could determine.

What has been said of the Gordon sand is equally true of the others of this group, so far as the writer's personal observations go. The oil pool in the Boulder sand in the Grubbs oil field is destitute of water. Many holes have been put down to the Boulder sand around this pool, but so far as can be ascertained, these have shown a close, hard sand, with no water, oil or gas. This sand also produces oil and gas in the Craig pool, near the trough of the Sewickley syncline. In this pool there is sufficient gas to flow the oil. No salt water is reported from any portion of this territory. In the Duff City field the Snee and Thirty-foot sands carry oil near the crest of an anticline in an apparently dry sand. The Criders pool is in the Snee, near the axis of the Brush creek anticline, with apparently no water in this sand below the oil. In the instances cited above, it is extremely difficult to find a plausible theory to account for the accumulation of these pools in apparently dry rocks on or near the crests of anticlines.* By the Anticlinal Theory pools in dry sands should occur at or near the bottom of synclines, or at the upper margin of flat areas, where the pools are small. Such occurrences might be accounted for in a few of the cases mentioned by attributing their peculiar locations to barriers of impervious rock in the oil sand which prevented the downward movement of the oil by gravity. But in the larger fields, like the Coraopolis and Wildwood, and the Fifth sand pool in the McDonald field, this explanation will hardly hold. A brief statement of the conditions found in the last-named pool will place the situation more clearly.

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*The Fifty-foot contours on Plate 1 do not bring out the smaller structural features in and near the oil pools to which reference is made.

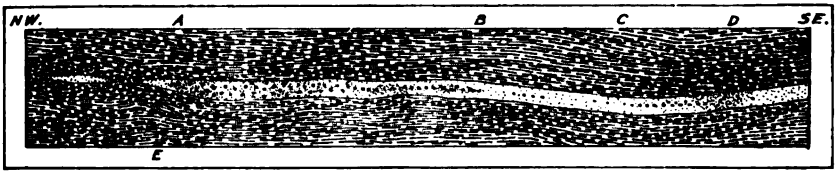

Fig. 21. Showing a northwest-southeast section of the Fifth Sand across the McDonald oil pool. The horizontal distance is about 12 miles. Both the dip and the thickness of the sand are greatly exaggerated. (If the vertical and horizontal scales were the same in the figure, the Fifth Sand would appear as a thin almost straight horizontal line.)

A B, McDonald oil pool; C, axis of Ninevah syncline; D, small pool of gas; E, some gas. This sand shows little or no salt water.

Fifth Sand Oil Pool in the McDonald Field. This pool lies along the irregular western flank of the Nineveh syncline. It is about 10 miles long by 4 miles wide at its widest point. This area has been drilled full of holes, and some single wells from the Fifth sand alone have flowed over 10,000 barrels per day from holes ranging from 2,200 to 2,400 feet deep. After producing for 18 years these wells show only here and there a trace of salt water in the Fifth sand. This pool lies parallel to and very close to the edge of the Fifth sand, which pinches out completely near the upper margin of the producing area. Fig. 21 shows a section across this pool near the middle, from the trough of the Nineveh syncline northward to the edge of the sand.* From this figure it will be seen that the McDonald pool lies along a gently sloping terrace, from which the rocks dip more rapidly southeastward to the Nineveh syncline. Within the pool the Fifth sand is in most cases a very open conglomerate sand varying from 0 to 40 or more feet in thickness. On the slope below this pool to the bottom of the Nineveh syncline the sand is closer and harder and carries fewer quartz pebbles, but it has often been found to have a good pay with no oil or gas and *little or no water.* On the side of the syncline above the oil pool the sand is usually close and hard, carrying no oil, some gas, and no water. It pinches out entirely in a short distance in this direction.

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*In this section the dip and thickness of the Fifth sand is greatly exaggerated. If the horizontal and vertical scales were the same in this drawing the sand would appear as a thin, almost straight line, with a dip hardly perceptible to the eye.

What explanation can we provide for the accumulation of an oil pool of this type? Since the bed gives up little or no water it might be considered as not saturated. In such a case, by the Anticlinal Theory, the oil should have been derived from the sandstone up the slope from the pool. This is manifestly impossible since there is no sandstone in that direction. And it is impossible to imagine that this oil has come from the shales above or below the producing area when we consider that the pressure was sufficient to raise a column of oil 6 inches in diameter 2,400 feet at a rate sufficient to produce 10,000 barrels per day. It has been suggested that in pools of this type the sand was once filled with water, and that it has been removed subsequent to the formation of the oil pool. The writer does not believe this could be true in this instance. If such were the case, hydration and drainage would be the principal means of this removal. In rocks of this type it would be ridiculous to attribute all of such work to hydration. The greater part (if removed at all) would be drained away by gravity caused by slow structural changes. If this be the case here, how could a difference in specific gravity equal to half the weight of the oil develop such an enormous pressure in rising along the western slope of the syncline? If this were possible, when the water was being drained away would this pressure, plus gravity, not cause the oil to flow back down the slope on the track of the disappearing water? And would not the ultimate location of the pool have been along the trough of the syncline? If the sand is still saturated with water, why did it not flow into the wells through back pressure from the oil and gas, since by the theory the rock is admittedly porous enough to allow the passage of oil by difference in gravity of the oil and water? Also if the oil come up the slope, why do we have a gas pool occurring at a lower level than the oil pool?

The same conditions prevail in a longitudinal section of this pool, with the exception that the oil rock has less dip, so that no explanation is offered in that direction.

What has been said regarding the Fifth sand production in the McDonald pool may be stated in much the same manner for all the pools named above. They are invariably found in small lentils of open, porous rock surrounded by harder, closer areas of the oil sand. We can not imagine for a moment that such a porous area in the sand has held this body of oil from the time the rocks were deposited. Nor is it clear how capillary action could cause such accumulations. This force can act only in the absence of water, a small quantity of interstitial water being sufficient to bar such action. All geologists will agree that there is little chance that these rocks are absolutely dry, but that they must of necessity carry a relatively large amount of intersticial water, though not a sufficient amount to saturate them, in which case no water would appear in the wells except under the most favorable conditions of dip and porosity.

From this brief outline it will be seen that the writer does not consider that the geologic history of these pools, and all similar ones, can be explained by the theories which are usually put forward.

It is hoped that future investigations along the lines now being pursued will result in a better understanding, not only of this phase of the perplexing problem of oil and gas accumulation, but also of many other equally important questions, the solution of which will result in substantial gains both to the producer and to the geologist.

CLAY AND SHALE.

GENERAL STATEMENT.

Pennsylvania ranks second in the United States in the production of clay products. In 1907 clay products to the value of $20,291,621 were produced, according to the statistics of the Division of Mineral Resources of the U. S. Geological Survey. Of this amount the largest single item was for fire brick, $6,907,904. Common brick came close behind, with a value of $6,353,799. Over $1,000,000 of vitrified and front brick were produced. The other products ran under $1,000,000 in value (the various kinds of pottery taken together will run over $1,000,000).

The clays of Pennsylvania occur as: first, residual clays, due as a rule in the part of Pennsylvania here studied to the decay of shales, shaly sandstones, or argillaceous limestones in place; second, alluvial clays deposited along the present stream valleys; third, clays deposited in the high level abandoned river channels and on river benches; fourth, coal measure plastic clays, usually underlying the coal beds; fifth, coal measure flint, non-plastic clays.

RESIDUAL CLAYS.

The term residual, as applied to clays, is sometimes restricted to those originally formed from the breaking down of feldspars. The clays so formed are kaolins mixed with the other elements of the original rocks except those that have been dissolved and removed in solution. Used in this sense there are no residual clays in southwestern Pennsylvania. The term is here used, however, to denote clay formed in place by the decomposition of shales, shaly sandstones, or argillaceous limestones. Such clays will be found wherever the underlying rock is highly argillaceous. They will be impure in proportion as the underlying rock contains sand, lime, or other material. Such deposits are usually of very limited thickness. They are utilized principally for the manufacture of ordinary red brick in a small way for neighborhood use.

TRANSPORTED CLAYS.

Under this head for our purpose will be considered those clays that have been carried a greater or less distance and redeposited in river bottoms, either in the past or present. As a rule these clays are apt to be well mixed with sand and other materials. In places water currents or other conditions that tend to sort the transported material have persisted long enough to allow the laying down of beds of a fair degree of purity, and of sufficient depth and area to make a commercially workable deposit. This is especially true of the old abandoned river valleys to be found adjacent to most of the larger streams in southwestern Pennsylvania. Mr. Campbell has worked out the character of these deposits in several places where valuable deposits of clay exist. He has found in many cases that following up stream from the body of clay the deposit tends to become more sandy and coarser, until finally only the coarse river gravel is seen. He has explained these conditions on the supposition that the channel was dammed just below the clay deposit, pounding the waters so that the coarse material was dropped at the upper end of these pounded waters, while only the finest material reached the lower end. He has suggested ice as the agent of the damming, and the time as during the Ice Age of Pleistocene time. These clays are utilized at several places along the Monongahela river, in one place yielding 14 feet of white clay. In that region they have been utilized mainly in the manufacture of jugs and other stone ware. At Johnstown clays of this character have been used with the underlying coal measure shales in the manufacture of buff and brown building brick. It is probable that it will be only here and there that clay of sufficient purity will be found in these deposits.

PLASTIC CLAYS OF THE COAL MEASURES.

Practically every coal bed in the coal field of Pennsylvania is underlain by a bed of clay. These clay beds have a thickness of from 1 or 2 feet up to 12 to 15 feet or more. As a rule the clay beds are less than 4 feet thick. The use of the word clay for these beds has sometimes been questioned, and some writers use the word shale to describe all such deposits. There is also a very common failure on the part of those who prepare records of core drills to distinguish between clays and shales. Shale is usually defined as a somewhat hardened rock that will split more or less readily into irregular laminae or plates parallel to the bedding. They present almost endless varieties of texture and composition, and pass by imperceptible gradations into a variety of other rocks. The criterion however, that determines whether any rock is a shale or shaly, is its ability to split into more or less thin leaves parallel to the bedding. The term shale is usually confined to a fine-grained rock having those characteristics, and such rocks are usually argillaceous in character, and the term shaly applied to rocks of other composition having that physical character. It is true the term shale is sometimes used for rocks in which locally the splitting is rather obscured by the shale having a tendency to weather out in little blocks rather than thin leaves. Most of the shale used in Indiana for tile, paving blocks, et cetera, is of this character. Yet even here the blocks are bounded on two sides by the bedding plane faces. On the other hand, the so-called clays under the coal beds do not usually exhibit the slightest tendency to such splitting. The clay as dug comes out with the irregular fracture of an ordinary lump of dirt. Often these lumps show smooth slicken-sided surfaces of a conchoidal shape, meeting and cutting each other in all directions, and indicating that the clay while in the earth has adjusted itself by movement to the varying pressures under which it has existed.

Two theories may be advanced to account for the lack of shaly structure of the clays under the coals: first, that these clays were deposited in the bottom of shallow bodies of water under conditions that allowed the gradual but nearly continuous deposition of clayey matter, whereas in the case of shales the deposit was periodic, following successive periods of rain or from other cause, so that the surface of each successive layer had time to harden slowly, or otherwise change so that a plane of separation would afterward exist betwen it and the following overlying layer; and, second, that these clay beds would have formed ordinary shale beds except that they have served as soil for the growth of the vegetation that composes the overlying coal bed, and that the roots of the plants in their growth through this soil would naturally break up any horizontal structure it may have had. At the present time it is difficult to determine how much weight the first theory should have, if any. The structural resemblance of these clays to the "plankton" being laid down in the clear lakes of the northern United States is striking, but not the chemical character. On the other hand, the second theory seems sufficient to any one who has examined in the face of a cutting the lack of shaly structure in the surface soil where such soil has been subjected not only to the agency of roots of growing plants, but to the burrowing of ants and other small animals, and where this soil is on a flat surface involving no horizontal movement, and is obviously the result of weathering of underlying shales.

In some places the coal was originally laid down on a sandy deposit instead of on an argillaceous deposit. In such cases it is usually found that the sandstone has been affected in practically the same way as the clays more commonly found. The top of the sandstone bed for from 1 to 4 or 5 feet has usually lost all trace of the bedding shown in the unaffected underlying portion of the sandstone bed. If dug into. this sandstone usually comes out in nodular irregular blocks or lumps. Examined carefully, both the clay and sandstone under these conditions are found to be cut by numerous vertical lines. Closer examination shows these lines to be the casts or molds formerly occupied by the roots. These are usually very conspicuous in these under sandstones, and may have been entirely obliterated in the case of clays that are much slickensided.

In some cases it is difficult to account for the presence of a clay rather than a shale, as when below the Upper Freeport coal a clay is found below the Upper Freeport limestone as well as between the limestone and the coal. As there is frequently found flint clay associated with the bed below the limestone, and as the flint clay is supposed to have a different origin from the soft clays just described, it seems possible that in this and similar cases the plastic clay may have its origin in accordance with the first theory, that is, that it was laid down under peculiar conditions that not only allowed the careful selection of the material to be deposited, but that this material when selected was deposited so that no shaly structure developed under the weight of the rocks laid down afterward. The subject is one admitting of considerable study.

Furthermore, these under clays and under sandstones are alike in two other particulars in which they differ from the shales and sandstones not associated with coals, first, they incline to be lighter in color. In particular cases this is not always apparent, but taking a number of cases it becomes quite striking. Where shales usually range from bluish-gray to black, and sandstones from gray to red, yellow, brown, and black, the under clays will range from a dark-drab to pure white, and the under sandstones are usually gray or nearly white. Light-gray, cream-colored and white under clays are common, but cream-colored or white shales are almost unknown. In the second place, the under clays and sandstone agree with each other and disagree with other shales and sandstones in containing very small amounts of the alkalies and other "fluxes." Both of these facts are explained by the well proven fact that such vegetation as formed the coal, aided by the organic acids which are found in the soils, has the power of absorbing from such soil all or nearly all of the alkalies, iron and sulphur they contain. The removal of the iron oxides takes away the reds, yellows and browns that they may have contained, leaving them gray or other light color.

The difference in the amount of "fluxes" is evident if any comparisons be made of the analyses of the shales and under clays. For example, recent analyses of 18 shales from the coal measures of Indiana showed them to range from 8.85 to 15.91 per cent. of fluxes. with an average of 12.98. Similar analyses of 17 under clays from the same region gave a range for the fluxes of from 1.79 to 12.40, with an average of 6.77. Evidently the shales are better suited for the manufacture of paving brick, where a certain amount of melting in the clay is desired, in order that it may "vitrify" or harden into a glass in cooling, while the clays are adapted to the manufacture of refractory brick or ware. These under clays are usually all designated fire clays. In the analyses just cited, it is evident that the under clay with only 1.79 per cent. of fluxes will make a high grade fire brick, as indeed it does, while the under clay with 12.40 per cent. of fluxes would not be classed as a fire clay at all. Comparing the two sets of analyses it is found that 14 of the 18 analyses of shales show over 12 per cent. of fluxes, while of the under clays 12 of the 17 run under 7 per cent. of fluxes, so that while it is a general rule that the under clays are fire clays, it is not universal.

The under clays of the upper part of the coal measures have been but little exploited. The "main clay" of the Pittsburg bed 8 inches thick has been used successfully at Courtney and Manown in the manufacture of clay forms for the open hearth and Bessemer steel process. In these cases the operations of mining the coal had developed a large volume of clay already available. So successful have these plants been that there seems no reason why similar plants should not be developed at other points where the commercial conditions warrant, especially where the clay is taken down in mining the coal. With the preceding exception all of the plastic under clays being developed belong in the Allegheny or Pottsville formations. Practically all of the Allegheny coals are underlain by clay nearly everywhere. Taken as a whole relatively little is known of the availabilty of the different under clays. Actual development in the area here studied has been confined almost entirely to four horizons, and to very limited areas on the outcrops of these horizons.

The Upper Freeport Clay. This usually runs from 1 to 3 feet in thickness, but in many places it is up to 10 or 12 feet thick. It is usually a deep buff color, but is sometimes a pale bluish-gray. It was formerly worked near the Summit Cut of the P. F. W & C. Railway on the New Castle quadrangle, where it is reported 8 to 10 feet thick. It is worked at Fallston on the Beaver quadrangle, where it has a thickness of up to 22 feet. It is said to make an inferior brick when used alone, but does well when mixed with the Lower Kittanning for building brick, its ferruginous character adding colors where desired. In Beaver county this clay is often more persistent than the coal. In come places in this county, as elsewhere, the clay is in two benches lying above and below the Upper Freeport limestone. In many places where it shows unusual thickness it is probable that the limestone has run out, allowing the two benches of clay to come together. At many points in the Connellsville Basin the plastic clay below the Upper Freeport coal is mined in connection with the Bolivar fire clay at that horizon, plastic clay being used to form the bond. It does not appear to have been extensively developed in other parts of southwestern Pennsylvania, though it is practically co-extensive with the Upper Freeport coal.

The Lower Freeport clay and Upper Kittanning clay have been but little explored or exploited. Thicknesses of the clay from 3 to 5 feet are not uncommon, though both clays will probably average much less. Locally 10 feet of clay is found below the Lower Freeport coal. At such times it appears to be in a bench that underlies the limestone.

Middle Kittanning Clay. In Beaver county the clay below the Middle Kittanning (Darlington) coal is persistent with a thickness of 5 to 7 feet. Where it has been prospected or opened, it is in general reported to contain too many iron nodules for most purposes. Locally it reaches a thickness of 15 feet. In the Clarion quadrangle this clay has been mined with a thickness of 4 to 6 feet near Hawthorne. It is made into Bristol glazed stone ware.

Lower Kittanning Clay. This is probably the most important plastic clay horizon in the State. Its large development has been in part because of its advantageous position close to the level of the river bottoms along the Ohio, and the adjacent transportation facilities thus given, and partly because of its quality and thickness. This bed furnishes most of the clay along the Ohio river from Beaver county, Pa., to Ashland, Ky. It is usually a dull gray color when fresh, turning creamy white on long exposure. The upper part is usually the purest, and it grades insensibly into sandy clay below, which is usually less plastic, harder and more shaly. Different parts of the bed may be used according to the product to be made. For stone ware only the upper, more plastic part is used. For sewer pipe a mixture of the bed as a whole is suitable. This clay will probably average thicker than any other in the coal measures. While it is often only 1 or 2 feet thick, it will probably average between 5 and 7 feet over large areas. Thicknesses of 10 to 12 feet are common. At Clearfield the clay at this horizon is probably combined with the Clarion clays below, so as to make almost or quite 40 feet of clay. This clay is extensively mined in Beaver, Fayette, Armstrong, Clarion, Clearfield and Cambria counties. The clay is shown on the map by the line of outcrop of the Lower Kittanning coal, where that outcrop is shown. In many parts of the area a valuable flint clay is associated with this plastic clay.

Clarion Clays. Clays associated with the coals of the Clarion group have been more or less extensively exploited in many of the counties. In Beaver county it has been worked by Mr. Hice, who reports it superior to the Lower Kittanning clay, containing a smaller amount of iron and probably of alkalies, standing more firing, and burning to a much whiter color. It has a reported thickness of from 6 to 12 feet. It is not well situated in that county for mining. In the Kittanning and Rural Valley quadrangles this clay is extensively mined. It is there a high grade plastic clay suitable for gray or buff building brick and sewer pipe, tile and pottery, and as a bond for fire brick. It is from 6 to 10 feet thick, often with a layer of black clay on top. While usually sandy toward the bottom, it often tends to run into sandstone. In Clarion county both Clarion coals are underlain by often 5 feet or more of gray clay. It is used near New Bethlehem in connection with the overlying shale for hollow building brick and drain tile. At that point there is 10 feet of clay, of which the lower half is hard and sandy. In many places the lower sandy portion of this clay passes over into a gannister rock, being a white sandstone resembling the clay in its structure.

Valuable plastic clays occur beneath the Brookville coal in the south part of the State, and with the Mercer coal in many parts of the State. They are, however, usually mined mainly in connection with the valuable flint clays which occur at those horizons.

FLINT CLAYS.

General Statement. Flint clays are the main source of the high grade furnace linings and other refractory wares. In a large measure the great furnace industries of Pennsylvania are dependent on the flint clays for their continuance. This great demand has given a high value to all suitable flint clays, for all flint clays are not equally refractory. Unlike the plastic clays, which as a rule must be favorably situated with respect to commercial conditions to be of any value as clay, the flint clays are constantly being sought, and when found of the desired quality will be mined almost without regard to commercial conditions. Many branch railroads and switches, often many miles in length, have been built back among the hills to reach extensive deposits, yet strangely enough the geology of flint clays has received almost no attention from the writers of clay reports and books on the subject of clay and clay products. The writer therefore feels constrained to add a few notes on flint clays and their occurrence.

Chemically a flint clay of the best grade has almost the composition of pure kaolinite. In the table below are three analyses from different parts of the bed from a deposit 2½ miles west of Blue Ball, Clearfield county. The specimen photographed in Plate XIII A, is from this deposit, and would probably correspond closely with the second or third analysis. In the fourth column is placed for comparison the theoretical composition of kaolinite, or kaolin, as it is commonly known:

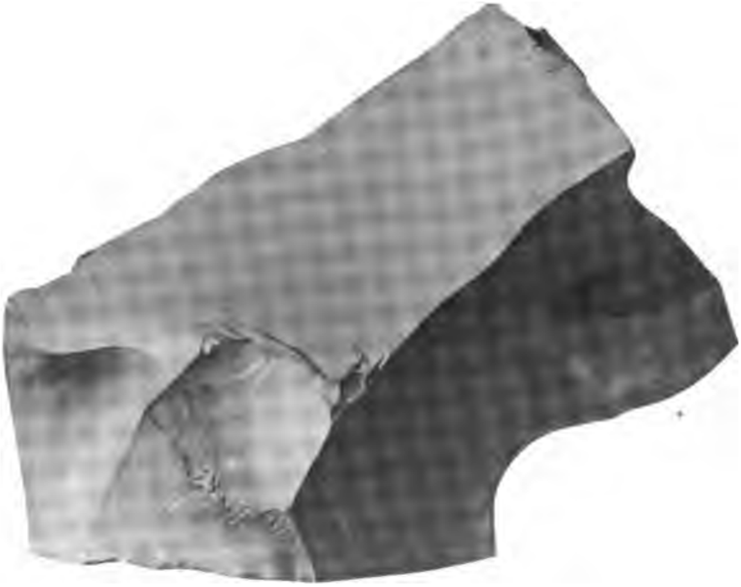
ANALYSES OF SELECTED SPECIMENS OF FLINT CLAYS, KAOLINITE AND INDIANAITE.

	1	2	3	4
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica (SiO_2),	42.700	43.350	44.550	46.4
Alumina (Al_2O_3),	37.600	37.550	39.000	39.7
Iron oxide (Fe_2O_3),	2.385	2.145	1.440	....
Titanium oxide (TiO),	2.500	2.825	1.700	....
Lime (CaO),	.112	.084	.028	....
Magnesia (MgO),	.270	.234	.072	....
Alkalies,	.730	.235	.530	....
Water and organic matter,	13.840	14.170	13.660	13.9

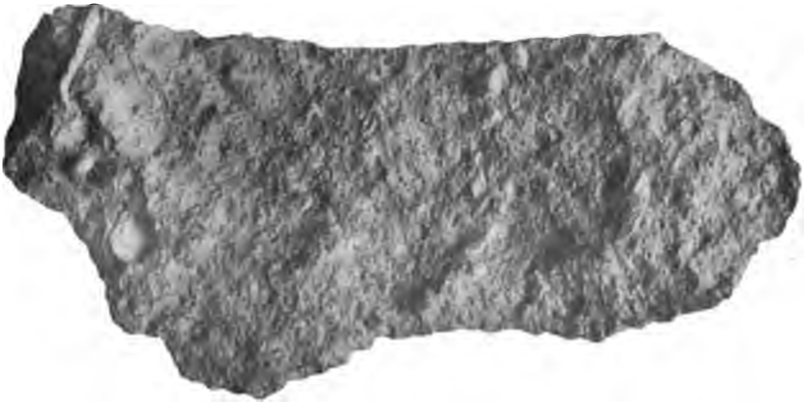
	5	6	7	8
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Silica (SiO_2),	44.75	46.75	44.60	43.19
Alumina (Al_2O_3),	38.69	38.17	40.65	41.60
Iron oxide (Fe_2O_3),	.95	.29	.80	....
Titanium oxide (TiO),	....	....	....	....
Lime (CaO),	.37	.67	.27	.15
Magnesia (MgO),	.30	.12	....	.06
Alkalies,	.35	.07	....	.45
Water and organic matter,	15.17	14.03	14.23	13.48

Nos. 1 to 3, upper, middle and lower portions of bed 2½ miles west of Blue Ball, Clearfield county, Pa. (McCreath, Second Geological Survey of Pennsylvania, volume H, page 121). No. 4, theoretical composition of kaolinite; No. 5, composition of indianaite, Lawrence county, Indiana (Noyes); No. 6, flint clay, Carter county, Ky.; No. 7, Gaylord flint clay, Sciota county, O.; No. 8, Stone City flint clay, Stone City, Ky. (Nos. 5 to 8, Twenty-ninth Ann. Rept. Dept. of Geology, Natural Resources Indiana, 1904, p. 392). The indianaite is a pure white deposit of a hydrous aluminum silicate. It occurs at the base of the coal measures in Indiana, and apparently has a somewhat similar origin to the flint clays. The Carter county, Ky., clay is probably from Olive Hill. It is a matter of some interest that the Olive Hill clay, as does that from Sciotaville, also occurs at the base of the coal measures. In that part of Kentucky and Ohio it there underlies the massive Sharon sandstone or conglomerate just as the indianaite underlies the massive Mansfield sandstone or conglomerate of approximately or quite the same age. The matter is of interest as suggesting the possibility of a closer relationship between the indianaite and flint clays than is suggested by the analyses alone.

As far as known to the writer flint clays have not been studied mineralogically. Whether kaolin is the base, or some closely related mineral, I do not know. It is evident, however, that in its best



A. High grade flint clay, showing typical grain and fracture. From 2½ miles west of Blue Ball, Clearfield county.



B. "Nodular" flint clay. From west of Curwensville, Clearfield county.

Plate XIII. Photographs of flint clays. (Photographs made in Photographic Laboratory of the U. S. Geological Survey.)

grades it approaches very close to kaolin in composition, and to that extent differs from the clays and shales, that usually have a much larger amount of free silica and other impurities.

Physically a good flint clay differs strikingly from an average clay or shale. The upper figure in Plate XIII is from a photograph of a piece of flint clay from the deposit west of Blue Ball. It shows well the characteristic features: the smooth, fine-grain, the conchoidal fracture, the sharp edges between the conchoidal breaks. The color is a gray-drab, not very different from that of the engraving, and a hardness when fresh nearly that of many limestones, that is, it will ring under the hammer, requiring often repeated blows to break off pieces of any size. After being out in the weather a long time it tends to become more brittle, so that a sharp blow with a heavy hammer on a block a foot cube may break it into a hundred pieces, but each little piece has all the sharp edges and the conchoidal faces of a piece of quartz flint broken down under similar conditions. The geologist unacquainted with the rock hardly hesitates to call it limestone on general appearance until he has tested it with acid.

The rock is not all of the high grade described, either chemically or physically. The lower figure of Plate XIII is from a photograph of a specimen of what is known as nodular clay. This as a rule will make brick of only second grade. Flint clay, as is well known, is non-plastic, and must be mixed with a certain percentage of plastic clay in order to be moulded into bricks. The percentage of plastic clay varies according to the use to which the fire brick is to be put, or the grade of fire brick being made, and also with the refractory qualities of the plastic clay. The occurrence of flint clays is a matter that has been but little discussed in reports or text books. In some cases the flint clay occurs as a deposit sharply delimited by rocks of quite different character, but it usually occurs associated with shales and clays somewhat similar in physical aspect. In some cases the limits of the two associated deposits are sharply drawn. In other cases they are not. In some cases it would appear to be an original deposit in the regular sequence of layers; in others it would appear to be a secondary alteration deposit. Examples may be cited illustrating these various occurrences.

The first 50 to 60 feet above the Upper Freeport coal up to the Mahoning coal in the central counties is generally filled with shale. This shale is usually very fine grained and olive in color. In parts of the section the fineness of the grain seems to increase until the shale on fracturing presents surfaces as smooth as an ordinary piece of paper. This condition may be observed commonly over Clearfield, Cambria, Indiana, Jefferson, and other counties. In many sections that is as as far as that phase of the shale goes, but in many other sections in this same stratigraphic position, the fine grained shale can be observed changing from a somewhat fissile shale to a shale having the conchoidal or hackly fracture of flint clay, with apparently its hardness, brittleness, et cetera. In some cases the change goes no further than would be described by flinty shale, that is, it is still distinctly a shale, but with decided flinty tendencies or characteristics. On the other hand, it may change over into a typical flint clay. In some cases the flint phase is rather sharply defined. More often it grades imperceptibly into the shale above and below. Usually the thickness is not over two or three feet with indefinite limits, but in some cases it reaches a thickness of 7 or 8 feet. An analysis of this clay from such an occurrence west of Dilltown is given below:

PARTIAL ANALYSIS OF FLINT CLAY FROM NATURAL EXPOSURE WEST OF DILLTOWN.

(E. C. Sullivan, Analyst.)

Silica (SiO_2),	50.3
Alumina (Al_2O_3),	21.3
Ferric oxide (Fe_2O_3),*	10.4
Magnesia (MgO),	0.61
Lime (CaO),	0.39
Soda (Na_2O),	0.18
Potash (K_2O),	1.14
Titanium oxide (TiO_2),	0.90
Loss on ignition,	12.00
	97.22

In this case, as is usual with flint clay at this horizon, it is very high in iron. This shows in the color, which nearly everywhere has a decided olive cast.

A similar case, only that the adjacent rock is clay, occurs in northeastern Kentucky. There over a large area just about in the middle of what may be the Lower Kittanning and Clarion clays combined is found a thin bed of flint clay. It has all of the hardness, brittleness, conchoidal fracture, and other physical charactertistics of flint clay. As observed in a large number of road sections it has a thickness often of only a few inches, though sometimes reaching a foot or two. In many of these sections it attracts attention by being nearly or quite black in contrast with the light-gray color of the clay above and below it. In other cases it is light-gray in color. As mined at Willard, Carter county, Ky., though only 4 inches thick, it was shipped to Olive Hill and elsewhere and pronounced equal or better than the Olive Hill clay. In this case, as in the one first

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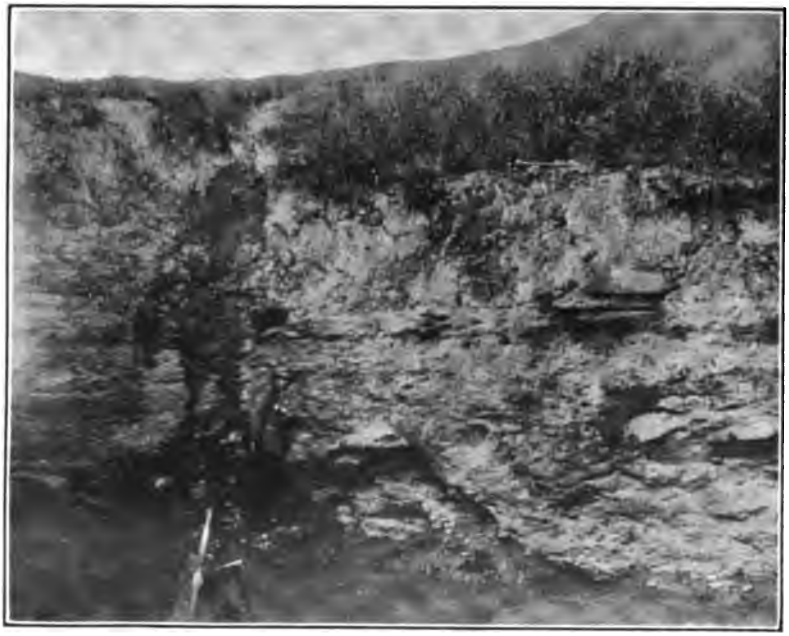
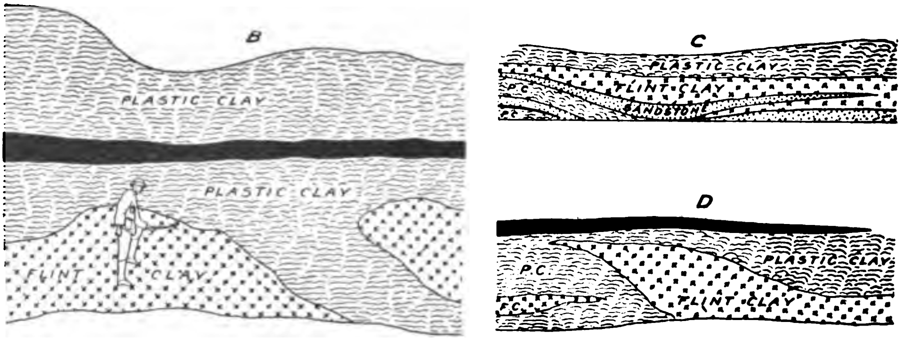
*Total iron calculated as Fe_2O_3.



A. Photograph showing occurrence of flint clay in quarry north of Sligo, Clarion county.



B. Key sketch of photograph. **C. D.** Sketches showing occurrence of flint clay below Lower Kittanning coal, as exposed in railroad cuts between Curwensville and Clearfield. (G. H. A.)

Plate XIV. The occurrence of Flint clays below the Lower Kittanning coal.

cited, the bed seems to grade off into the clay above and below, rather sharply it is true, but having no sharp break between the flint clay and the other.

The upper figure of Plate XIV, which is from a photograph taken in a clay quarry north of Sligo. In the upper part of the quarry is the clay between the "B" coal and the coal below, which is here 22 inches thick and shows in outcrop about 2 feet above the head of the figure. Under the coal for 4 feet is soft, light-drab plastic clay. Below that is 6 feet of good flint clay. The point of interest is that a little to the right of the figure the flint clay ends abruptly against the plastic clay, which there descends to the bottom of the quarry. Still farther at the right is seen another irregular body of flint clay apparently imbedded in the plastic clay. These relations are emphasized by the sketch in the lower left hand part of the same plate. In the lower part of the same plate are two sketch diagrams to show the occurrence of flint clay and plastic clay in railroad cuts between Curwensville and Clearfield. In these and other cases that might be given, the occurrence of the flint clay is difficult to understand on the basis of difference of character in the original deposit.

Other factors to be noted are that the flint clays often occur entirely separated from any coal bed. When associated with a coal bed, as they usually are, it is generally found that they are separated from the coal by some plastic clay from a few inches to several feet, or by other rock, so that it is questionable whether the juxtaposition of the coal and flint clay has any organic meaning.

In the thick bed of plastic clay the flint clay may occur in any position in the same mine, sometimes at the bottom, sometimes at the top, or in any intermediate position, sometimes running out altogether, sometimes forming the whole bed, though as previously stated, there is almost invariably at least an inch or two of soft clay between the flint clay and an overlying coal bed, if the clay, as is generally the case, be overlain by coal.

There is a third mode of occurrence that though not common, the writer has seen in several places, in which the flint clay is intimately associated with sandstone, not as a bed in the sandstone, but as irregular fragments scattered all through the sandstone. Sometimes the clay is in the form of small pellets one or two inches in diameter scattered all through the rock, and making but a small percentage of the rock. In other cases it is in large lumps 6 or 8 inches or more in diameter, and making up more or less half of the rock. In still other cases the clay is in large masses, but grades over into sandstone in short distances, often within one or two inches. In some cases the sand is in the condition of sandy masses of clay in the midst of a much purer bed. The uncertainty in the occurrence of this clay is well illustrated by one of the clay mines in Clearfield county. As the territory was not far from other operating mines, only a single test drilling was put down. This found 5 feet of high grade flint clay. An entry was then started, and found only a worthless mixture of clay and sandstone until the drill hole was reached, the entry catching the drill hole just at one side. In the center of the entry 3 feet from where penetrated by the drill, the good clay had thinned down to 3 inches, and it was later found that the drilling had entered a "pot" of fine clay about 40 feet in diameter.

The differences in the occurrence of the flint clays that have been described suggest possibly quite different modes of origin. In the first case the flint clay seems to form a widely distributed regular layer in the midst of either clay or shale, from which it probably differs not very greatly in composition, and into which it seems to grade. In the second case the flint clay occurs as irregular masses, sometimes of considerable lateral extent, and often lying obliquely to the bedding, and with usually rather sharply defined contacts with the adjacent clay.

In the first case it would seem as though, due to some cause not explained, there had been for a time in the regular process of deposition a gradual decrease in the amount of impurities and of free silica in the clay matter being deposited, with possibly a decrease in the amount of colloids, if those actually have to do with the plasticity and with possibly other differences not recognized that go to differentiate the flint clays from the soft plastic clays. These conditions having existed a short time, there was a return to the more usual conditions under which the main bed of soft clay was laid down.

In the second case, if it be assumed that the bed of soft clay with which the flint clay is associated was deposited under water and probably quiet water, it is difficult to conceive of any conditions that would allow the simultaneous deposition of these irregular masses of flint clay lying in the soft clay in irregular and often transverse positions. On the other hand the writer is unable to suggest any adequate and satisfactory cause for the production of the change in the original clay bed. It is possible that a careful chemical and microscopical study of the flint clays and the adjacent shales and clays might throw some light on the problem. It has been suggested that the flint clays represent sub-areal deposits laid down in depressions by wind or the wash of rains, but it appears to the writer as difficult to explain the widespread deposits of uniform thickness of the first class as the extremely irregular deposits of the second class on this basis.

One other factor should not be omitted in considering the origin of these clays, that whether irregular or not they appear to occur only at a limited number of definite horizons, but at those horizons they are found recurring, though not persistent, over very wide areas. Thus flint clay recurs a short distance below the Lower Kittanning coal all the way from central Pennsylvania to northeastern Kentucky. Flint clay in the horizon of the Bolivar clay is found here and there all over the area of outcrop of the Upper Freeport in Pennsylvania, and so in greater or less degree of the other horizons. The reader may draw his own conclusions.

Stratigraphy of Flint Clays. The highest stratigraphic position at which flint clay has been found in Pennsylvania appears to be about 130 feet above the Upper Freeport coal in the lower part of the Conemaugh formation. This has only been reported as found and worked at one point. At Layton, on the Youghiogheny river, the clay is from 2 to 5 feet thick, underlain by plastic clay to give a total thickness of from 6 to 20 feet. On the west side of the river where it is pierced by the Washington run tunnel the clay is 3½ feet thick, underlain by 12 feet of greenish shaly clay, and that by 25 feet of sandy shale and thin sandstones. Over the clay are 10 feet of shaly and thin sandstones, and above that 25 feet of coarse sandstone.

Upper Mahoning Clay. In Beaver county where the Upper Mahoning interval is commonly shaly, a portion of this shale tends very persistently to assume a flinty character, and in places this becomes a typical flint clay of possibly commercial value. It lies 10 to 20 feet below what has been correlated as the Brush creek coal, and 70 to 90 feet above the base of the formation. It has a characteristic rusty color of orange brown or ochre, but the hardness and flinty fracture is even more striking. This bed is to be seen on nearly all the roads, where its horizon is crossed, and even when wet it crackles sharply under the buggy wheels. It is so widespread in this region and so readily recognized that its position will be shown on the map of the New Castle quadrangle when published. The fresh clay is a yellowish-gray. It has been prospected one mile east of New Galilee, where it is from 12 to 20 feet thick.

Lower Mahoning Clay. In the lower half of the Mahoning interval a very similar clay or flinty shale occurs in Clearfield, Cambria, Indiana, Jefferson and the other eastern counties. This clay is usually from 10 to 29 feet below the Mahoning coal, and from 30 to 40 feet above the Upper Freeport coal. It is so like the Beaver county flinty shale as to suggest the possibilty that the two are the same, and that the correlation of the Upper Freeport coal in the two areas does not agree. This clay appeared everywhere to be too ferruginous to be of value in the manufacture of brick. The analysis of this clay from an outcrop near Wehrum has already been cited. Flint clay from this horizon is used east of Johnstown in connection with shales for the manufacture of pressed brick.

Bolivar Clay. Flint clays of the Allegheny formation are of a much higher grade than the last two described from the Conemaugh. The highest of these clays stratigraphically is the Bolivar clay. It lies from 10 to 25 feet below the Upper Freeport clay, coming just under the Upper Freeport limestone. It has been worked for many years at the type locality, Bolivar, on the Conemaugh river, where it has a thickness of from 6 to 25 feet. A flinty clay seems to recur at this horizon with great persistency all through the eastern part of the coal field of Pennsylvania. In Indiana county especially it is to be met with in a large number of the roads, where its horizon is crossed, and the same thing is only a little less true of some of the adjoining counties. In these road exposures the bed itself is seldom seen, but a short distance below the bloom or outcrop of the Upper Freeport coal the road will be strewn with the sharp-edge fragments of the flint clay. In the region northeast of Bolivar it has been but little mined, but to the southwest it has been the source of a large part of the clay used in the manufacture of the many fire brick needed in the coke ovens of the Connellsville district. Much of the clay is shipped from pits on the Youghiogheny river in the vicinity of Ohiopyle to Connellsville. A large plant at Moyer is supplied from pits near Heninger. In these pits the Upper Freeport coal is underlain by 3 or 4 feet of shale, and this by from 10 to 15 feet of flint clay. In this district and apparently all along Chestnut Ridge the clay contains much iron. Where weathered the iron is segregated into concretions or "ore balls" which can be removed by hand. Where unweathered the iron is disseminated through the clay, and this portion of the clay can not be used. The same bed has been mined at Layton on the Youghiogheny river, where it is said to be very refractory, and has been used for glass pots. It was formerly worked 3 miles above the mouth of Jacobs creek, and shows on Meadow run and Sewickley. Below Hunkers flint clay 0 to 6 feet in thickness is mined with plastic clay in many places. In Clarion, Indiana and Clearfield counties this clay presents an excellent appearance in road outcrops, but it has not been prospected or developed. South of Chicora in the western part of the Kittanning quadrangle this bed is 10 feet or more in thickness, and apparently has an extent of several square miles.

Upper Kittanning Flint Clay. In a few scattered places flint clay has been seen to occupy a position near the Upper Kittanning coal. n Clearfield county it was noted at a number of places near West- er, near McCartney, and near Graham station. In the Uniontown quadrangle there is a flint clay 80 to 90 feet below the Upper Freeport coal and 150 feet above the Pottsville sandstone. It has been mined at many points. It is 4 to 6 feet thick on Drague run in Springhill township. It is 6 feet thick on Dunbar creek. It is mined from pits along Youghiogheny river between Indian creek and Ohiopyle. Below Stewarton, one mile below the station and half a mile farther down stream, the clay is 10 to 12 feet thick, and immediately underlies a coal bed 15 to 18 inches thick.

Lower Kittanning Clay. Mention has already been made of the wide extent of flint clay associated with the plastic clay under the Lower Kittanning coal. In Clearfield county this clay has been extensively worked west of Woodland, where it is the upper bed, coming 90 feet above the Mercer clay, to be described later. As a rule in this region the bed is mainly soft clay, and as such is extensively worked at Bigler west of Wallaceton and west of Curwensville. Flint clay appearing in road sections a little below the outcrop of the Lower Kittanning coal has been found all through Clearfield county and northeastern Indiana county. At many places this flint clay does not appear to be of high grade. Too often it is very sandy. It covers a large area in central Clarion county in a belt extending across the north half of the Clarion quadrangle, as well as in the town of Clarion itself. In this district it often reaches a thickness of 6 feet or over. The clay is well up in the tops of the hills through much of the area. The clay is persistent in its occurrence, but varies greatly in quality. It has been used to a considerable extent, so its qualities are fairly well known. The best clay is light-brownish in color, fine-grained and moderately hard. Weathered pieces are bluish-gray on the exposed surfaces and are easily broken. An average sample gave as follows on analysis:

ANALYSIS OF AIR-DRIED SAMPLES OF FLINT CLAY FROM CLARION COUNTY, PENNSYLVANIA.

P. H. Bates, Analyst.	A	B
Silica (SiO_2),	58.96	56.46
Alumina (Al_2O_3),	25.60	27.69
Ferric oxide (Fe_2O_3),	3.32	2.55
Manganese oxide (MnO),	.07	.09
Lime (CaO),	.70	.42
Magnesia (MgO),	.25	.28
Sulphuric anhydride (SO_3),	.07	.14
Soda (Na_2O),	.15	.06
Potash (K_2O),	.36	.52
Water at 100° C.,	.80	1.40
Ignition loss,	9.90	10.64
	100.18	100.25

The analysis shows these samples to carry from one-fourth to one-fifth of free silica, and to be only about three-fifths clay substance, in contrast with the best flint clays, which contain almost no free silica, and are only up to 99 per cent. of clay substance, though most flint clays will run several per cent. below that figure.

An analysis of flint clay from this horizon in Clearfield county by McCreath gave as follows: silica, 50.150; alumina, 35.600; iron oxide, .845; lime, 1.112; magnesia, .160; alkalies, .070; water, 13.160. The similarity of this analysis to those of the same clay in the Clarion quadrangle suggests the possibility that this clay may generally contain a higher percentage of free silica than the underlying Mercer clay, which is described elsewhere. This suggestion is strengthened by the fact that in many places flint clay at this horizon is very intimately mixed with sandstone. As stated elsewhere, flint clay occurs at this horizon as far south as northeastern Kentucky.

Brookville Clay. Though not generally recognized as a flint clay horizon, along Chestnut Ridge in the south part of the State there is below the coal there correlated as Brookville-Clarion, a fine bed of flint clay. It was seen on Laurel Ridge east of Mt. Braddock, where it is from 8 to 10 feet thick, and of excellent quality, also on Tucker run, where it is from 4 to 14 feet thick, lying 20 feet above the Pottsville sandstone.

Mt. Savage Fire Clay (Mercer). The lowest fire clay, and one of the best, if not the best in the State, occurs in the Mercer group of coals. It has long been worked at Mt. Savage, Maryland, and the clay from that point has established a deservedly fine reputation. In Pennsylvania it has probably been longest and most extensively mined in Clearfield county. It was for a long time mined on Sandy Ridge in Center county, but the works there now are supplied from near Burly in Clearfield county. It is extensively worked at Woodland and in the region west of Blue Ball, around Burly, and between Burly and Blue Ball. It is found widely scattered all over the upland made by the McCartney anticline between Clearfield creek and the Pennsylvania Railroad to the east, as well as west of Clearfield creek. West of Clearfield syncline the coal is brought up again, and is mined in a large way west of Curwensville, west of Stronach, and at many points up Anderson creek on both sides. It also occurs in the valley of the west branch of the Susquehanna for several miles above Curwensville. As usual the clay is irregular, sometimes reaching a thickness of up to 18 feet, but more often being only 6 feet or less. In places the clay is all flint, and in others the flint clay runs out altogether. There is usually some soft clay with the hard clay, generally overlying, but often both above and below the hard clay. Over the soft clay is the Mercer coal, which runs from a few inches to 2½ feet. In general, the analyses of these clays as obtained by McCreath show from 44 to 46 per cent. of silica, 34 to 39 per cent. of alumina, 1.8 to 3.5 of iron oxide, 0 to 2.5 of titanium oxide, 1.06 to 3.02 of lime, .126 to .573 of magnesia, .830 to 5.75 of alkalies, and 4.885 to 14.170 of water.

This clay is mined at St. Charles and Climax, on Red Bank creek in Clarion and Armstrong counties, where analyses indicate as high a grade of clay as in Clearfield county. At St. Charles the clay as a whole has a thickness of from 8 to 10 feet, the flint clay varying as usual with the soft clay. At Climax the bed is 12 feet, composed of flint and soft clay in varying proportions. As a rule the flint clay makes up about one-third of the bed. From its position low down in the series this horizon has a very limited outcrop in the area under discussion.

SHALES.

Shales, which in some of the states, as Indiana, supply a large part of the argillaceous material entering into the state's output of clay products, in Pennsylvania play a very minor part. Except in a few places where they are used for paving brick, the shales are used at relatively few plants, and then usually mixed with clay. It is a matter of some interest, however, that the type of shales so extensively used in the state mentioned appears to be almost or quite lacking in southwestern Pennsylvania.

Purely argillaceous shales, or "clay shales," as they are commonly called, are seldom met with in Pennsylvania. Such shales are unctuous or greasy to the feel, much as is an ordinary clay, and when tested with the teeth show no trace of "grit," or free silica. Such shales may develop shaly structure rather feebly, tending to weather down from the quarry face, or cut, in little blocks or irregular cubes. A small amount of sand in the shale or in clay may be an advantage in preventing fire shrinkage. Difficulty is often experienced in obtaining a sandy shale in which the sand constituent is small and uniform.

Most of the coal measure shales of Pennsylvania carry a large percentage of sand, so much so that nearly all of the shales are described in the field notes as sandy shales. Indeed often the sand constituent is so large that the term sand-shale is in very common use by geologists as well as drillers and mining men, indicating a rock that is so evenly balanced between sand and clay that it would be purely a matter of personal choice whether to call it sandy shale or shaly sandstone. The difficulty is avoided by using the term sand-shale. From this very common medium a slight increase of sandy matter will result in a shaly sandstone, or a slight decrease, in a sandy shale, so that while field notes show a constant shifting in the same stratigraphic interval from sandy shale to shaly sandstone, the actual difference is often quite slight. In many cases the change is considerable, fairly quartzitic sandstones changing over into shaly sandstones and over into sandy shales in very short distances. It is possible that two other commercial factors have had a marked effect on the use of shale: the fact that in the east paving bricks are not used as much as in the central states, their place being taken by asphalt; and the fact that the almost universal hilly nature of Pennsylvania yields good natural drainage, so that the demand for drain tile is small. The use of tile for building in Pennsylvania has only a limited extent. Drain tile, paving brick and building tile are three of the most important products made from shale in the central states. To what extent the smaller use of paving brick and building tile in the east is a result rather than a cause is difficult to say.

Judging by development and use no particular shale horizon has been found especially suitable for the manufacture of clay products. Possibly certain parts of the Conemaugh or the lower parts of the Allegheny formation have been used more than others, though in these cases the position of the clay in the hill with reference to transportation may have in a large measure determined the clay to be mined. The Dunkard shales are reported in many places of fine texture and uniform in appearance. They are being used at Washington and Vance in Washington county for the manufacture of red brick. Red brick have also been made from some of the Monongahela shales in Westmoreland and Fayette counties, and also from shales in the upper part of the Conemaugh formation.

The Lower Conemaugh shales, especially, in the eastern part of the coal fields, those in the Lower Mahoning interval, are often rather free from sand, smooth-grained and uniform in color. The shale in the Buffalo interval (Punxsutawney shales) are used in the manufacture of paving brick at Punxsutawney. Shales from the lower part of the Conemaugh are also used at Johnstown and elsewhere.

As a rule the Allegheny shales are quite sandy, but they are used in many places in connection with the clays. The shales are usually found not to yield good brick when used alone, but to add strength and wearing qualities when added to the clay. In making bricks in some cases a foot or two of shale underlying the clay that is being mined is taken. Sometimes as much shale as clay is used. In other cases a considerable section containing a variety of beds is stripped, being all used together for some purposes and a variety of mixtures being used for other purposes. In Beaver county the shales between the Darlington and Lower Freeport coal, and between the Kittanning and Clarion coals have been used. In the

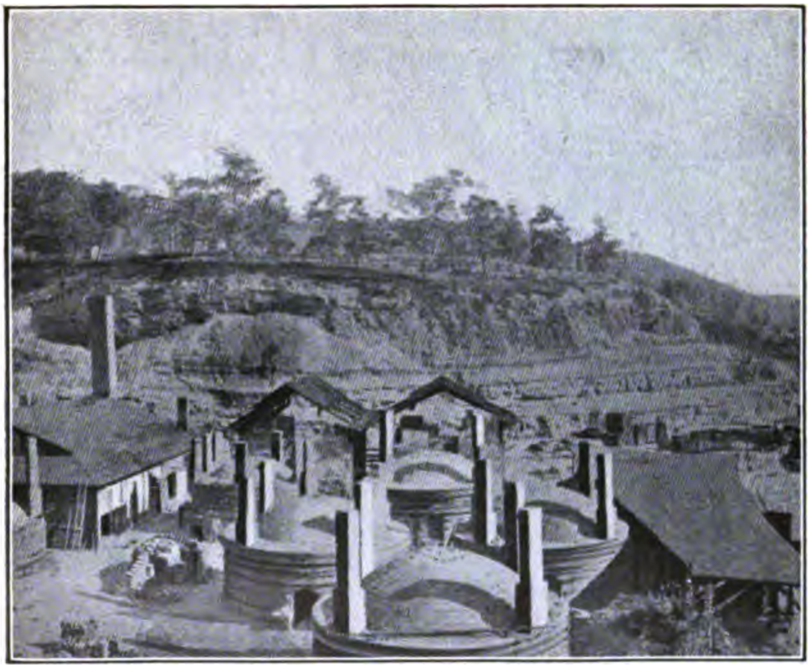


Plate XV. A. View of Kittanning Clay Manufacturing Company's Works at Kittanning.

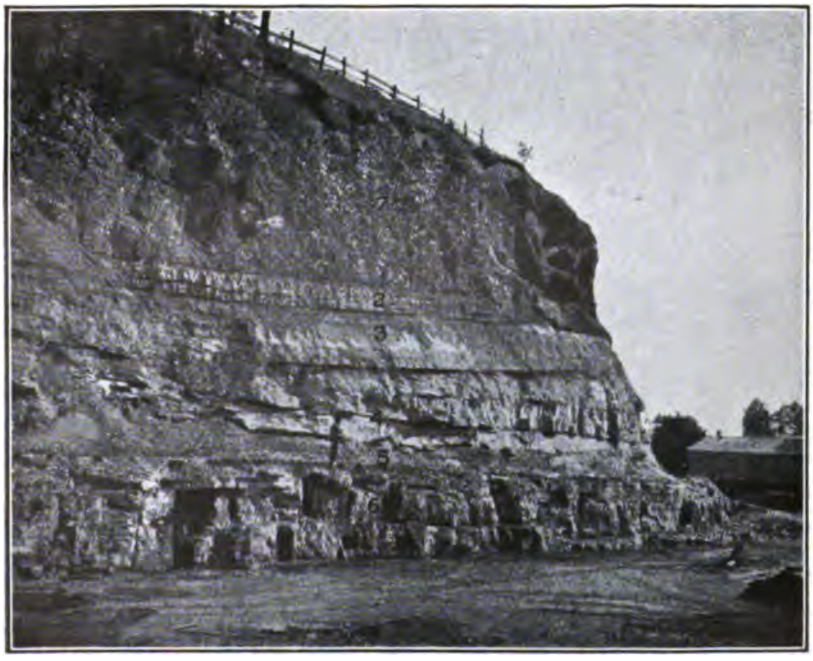


Plate XV. B. View of Kittanning Clay Manufacturing Company's Quarry at Kittanning.

Kittanning quadrangle the shales between the Upper and Lower Freeport coals are used at Cowansville in connection with 4 feet of clay, and with the clay is 5 feet of soft, plastic, greenish-gray shale with 12 feet of black shale below. At Kittanning the 25 feet of shale over the Lower Kittanning coal is used to make a fine vitirified brick for building fronts, while from the shales under the Lower Kittanning coal vitrified brick, building brick, buff fire brick, and sewer pipe are made. An analysis of one of the shales at Kittanning, according to Mr. McNees gave as follows: silica, 55.17; alumina, 19.92; iron oxide, 12.01; loss on ignition, 6.81. The Allegheny shales are extensively used in connection with the clays at Clearfield, the clay and shale below the Lower Kittanning coal being those used, and the same shale is used near New Bethlehem in Clarion county.

LIMESTONE IN WESTERN PENNSYLVANIA.

BY R. W. STONE.

GENERAL STATEMENT.

According to statistics collected by the Mineral Resources Division of the U. S. Geological Survey, the value of limestone quarried in Pennsylvania in 1906 was nearly $5,000,000. Of this amount, limestone to the value of $3,168,186 was quarried for flux. The other large items are.

For railroad ballast,	$602,128
For concrete,	486,682
For road-making,	251,200

Aside from the above the most widespread use of limestone in the past has been for fertilizer. For generations the farmers have burned it for land dressing, a practice which probably is more prevalent in Pennsylvania than in any other state. As shown by the figures the limestone industry in Pennsylvania is mainly dependent on the iron industry. In addition it is crushed for railroad metal, railroad ballast and concrete, and for chemical purposes, and it is dressed for paving blocks and for building stone. Limestone is also commonly burned for building plaster.

A use for limestone of increasing importance in this State is in the manufacture of Portland cement. For this cement a limestone of high grade is necessary. The magnesium carbonate must be less than 5 per cent., the amount of calcium carbonate should be at least 75 per cent., and the ratio of silica to alumina plus iron should be as 5 is to 2. However, as this ratio can usually be obtained by mixing with other raw materials, it is not necessary that the stone should possess a composition strictly within these limits. Suitable limestones are not abundant in western Pennsylvania, but the Vanport is almost universally low enough in magnesia, and the Upper Freeport usually so. The majority of the beds show in some places a suitable composition, but at other localities, and often in the same quarry, are entirely unsuitable. On account of the extensive outcrop of the Vanport limestone there is in this region a wide field for the founding of Portland cement factories.

The number of limestone beds in western Pennsylvania is considerable, though only a few of them have the quality and thickness to make them of value. Following is a table showing the principal limestone beds, their stratigraphic positions and maximum thicknesses.

LIST OF PRINCIPAL LIMESTONES.

Formation.	Name.	Approximate Stratigraphic Position.	Maximum thickness, Feet.
Dunkard formation, or Upper Barren measures.	Upper Washington limestone (No. VI).	Top of Washington formation, 250 to 425 feet above Waynesburg coal.	30
Monongahela formation, or Upper Productive measures.	Waynesburg limestone, ...	20 feet below Waynesburg coal.	35
	Benwood, or Great, limestone:		
	Upper member or Uniontown, limestone.	....	18
	Lower member, ...	120 feet above Pittsburg coal.	90
	Fishpot, or Sewickley, limestone.	Over 100 feet above Pittsburg coal.	30
	Redstone limestone, ...	30 to 70 feet above Pittsburg coal.	10
Conemaugh formation, or Lower Barren measures.	Pittsburg limestone, ...	20 feet below Pittsburg coal,	12
	Elk Lick limestone, ...	Midway between Pittsburg and Upper Freeport coals,	6
	Ames, or Crinoidal, limestone.		8
Allegheny formation, or Lower Productive measures.	Upper Freeport limestone,..	Below Upper Freeport coal,	28
	Lower Freeport limestone,..	Below Lower Freeport coal,	5
	Johnstown limestone, ...	Below Upper Kittanning coal.	10
	Vanport, or Ferriferous, limestone.	Below Lower Kittanning coal.	22
Pottsville formation, ...	Upper and Lower Mercer limestones.	Between Homewood and Connoquenessing sandstones.	4 3
Mauch Chunk formation, ..	Greenbrier, or Mountain, limestone.	40 to 50 feet above bottom of Mauch Chunk.	35
Pocono formation.	Loyalhanna, or Siliceous, limestone.	Upper portion of Pocono, ..	60
	Benezette limestones of Elk county.	....	7

Besides the beds named in the table there are many thin and local limestones, among which the Jollytown, Little Pittsburg, Middle Washington, and Lower Washington have been given names, but are nowhere known to be of much economic importance.

The thicknesses given in the table are the maxima and will not be found over wide areas. Only three of the beds average over 20 feet. Color and texture vary through wide limits, from nearly black to light gray or white, and from hard and compact to fossiliferous and shaly. In composition the range is from slightly calcareous sediments to limestone containing 96 per cent. of calcium carbonate. Magnesium carbonate is always present, in some cases amounting to less than 1 per cent. and in others exceeding 30 per cent. Alumina and oxide of iron may be present in any amount below 8 per cent.

Extreme variation, both in composition and texture, may be found in the same bed.

The following paragraphs are brief notes concerning the various beds of limestone outcropping in Pennsylvania. For further data reference should be made to the reports of the Second Geological Survey of Pennsylvania and to a paper entitled "Limestones of Southwestern Pennsylvania," by F. G. Clapp,* from which these statements are largely compiled.

Benezette Limestone. At a few points in Allegheny county a triple bed of limestone supposed to be of Pocono age has been found about 200 feet below the Olean conglomerate. The upper bed probably has a thickness of not over 7 feet, and the others are considerably thinner. The lower bed, when burned, is said to make excellent fertilizer. Analyses of samples taken from the upper and middle beds one mile west of the village of Benezette, show less than 2 per cent. of magnesium carbonate, but the proportion of siliceous matter to calcium carbonate in the upper bed is as 5 to 3.7, while in the middle bed it is as 1 is to 5.

Loyalhanna Limestone. The Loyalhanna limestone, which is the Siliceous limestone of the Pennsylvania Survey reports, shows in outcrop only where Chestnut Ridge has been cut through by the westward-flowing streams—Conemaugh river, Loyalhanna creek and Youghiogheny river. It is a fine-grained rock having a blue color, flint-like fracture, and no true cleavage. On its fresh surface it shows no signs of bedding, but where exposed for some time takes on a dull brown color and shows a peculiar cross-bedding. The weathered surface is very characteristic, being rough and pitted, and unlike any other rock in the region. This feature is well illustrated by the photograph, Pl. XVI B. The large proportion of silica in the rock gives it the general appearance of a sandstone rather than of limestone.

The Loyalhanna limestone is of greatest importance northward, being on Conemaugh river between 40 and 50 feet in both gaps. A similar thickness prevails in the Loyalhanna and Youghiogheny gaps, but southward the rock becomes thinner, being only about 18 feet thick on the National Pike and barely 4 feet near the State line. On Cheat river, West Virginia, it has wholly disappeared.

The limestone often occurs in two benches, separated by shale and sandstone. At a number of points it has been quarried for paving blocks and crushed for railroad ballast. Large crushing plants have been established on Conemaugh river above Blairsville, in the Loyalhanna gap above Latrobe, and in the Youghiogheny gap above Connellsville. This bed is well shown along the Pennsylvania Rail-

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*U. S. Geol. Surv. Bull. 249, 52 pp. 1905.

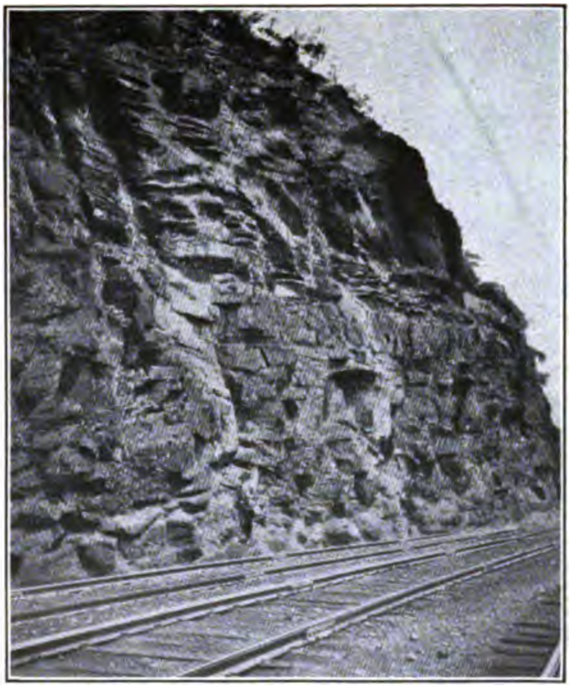

Plate XVI. A.—Loyalhanna limestone resting on sandstone of the Pocono formation, Allegrippus, Blair county, Pa. (Photograph by Chas. Butts.)

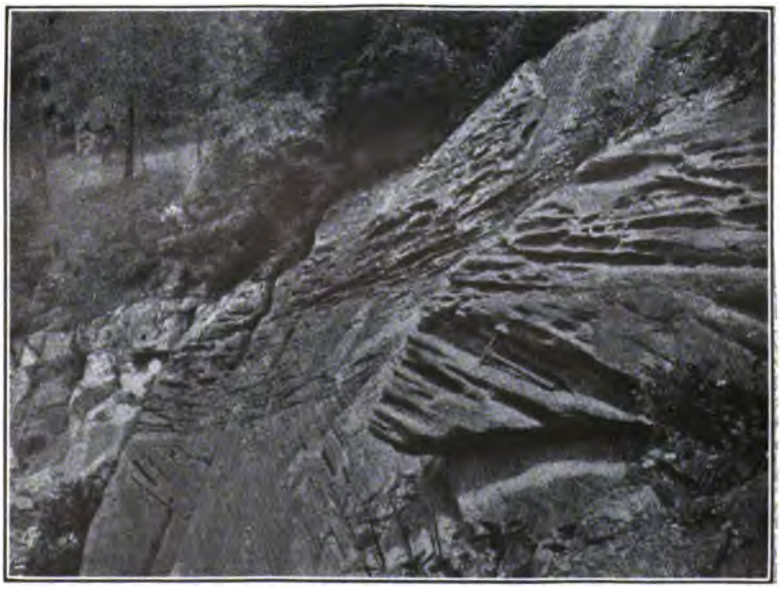

Plate XVI. B.—Weathered surface of the Loyalhanna limestone at the "Viaduct," 1 mile east of Mineral Point, Cambria county, Pa. (Photograph by M. R. Campbell.)

road, wherever its horizon is exposed, at points from Blairsville to the Allegheny Front, above Altoona. It is easily identified by its peculiar weathering, as mentioned above. This is well shown at Allegrippus, just above the Horseshoe Curve (Pl. XVI A), and where Laurel Hill and Chestnut Ridge are cut by the Conemaugh west of Johnstown. Near the last-named place it is quarried extensively and crushed for railroad ballast. Pl. XVI B, which shows the weathering peculiarities, is reproduced from a photograph taken at the "Viaduct," one mile east of Mineral Point, Cambria county.

Greenbrier Limestone. The Mountain limestone of the Second Geological Survey reports is the thin edge of a widespread deposit known as the Greenbrier in Virginia. It occurs in the Mauch Chunk formation, and it is known now in Pennsylvania as the Greenbrier limestone. Its greatest development in this State is along the southern boundary, where it attains a thickness of about 40 feet. Along Chestnut Ridge and Laurel Hill it outcrops about 50 feet above the Loyalhanna limestone. The Greenbrier is somewhat variable in character, the greater part of it being composed of thin beds of pure blue limestone, which often grade into shaly limestone and calcareous shale. In places it is very fossiliferous. Its principal use is in burning for fertilizer, for which purpose it is said to yield a lime of superior quality. Formerly it was used as a flux in iron smelting.

Mercer Limestone. Between the Homewood and Connoquenessing sandstones there are found somewhat infrequently two beds of limestone known as the Mercer or Tionesta. Their thickness does not exceed 4 feet, and their appearance is coarse-grained and sandy. They are very hard and tough, bluish gray, and an analysis of a specimen from Kelly's quarry, 4 miles east of Tionesta, Forest county, showed little over 1 per cent. of magnesium carbonate. The amount of calcium carbonate, however, was only 40 per cent. This limestone, like the Mercer coal, is unimportant.

Vanport Limestone. Universally known throughout western Pennsylvania as the Ferriferous limestone, because the buhr-stone ore rests on its upper surface, the name of the bed has been changed in recent reports to Vanport limestone, after a locality where it is quarried extensively. The Vanport is a bluish gray limestone of a good degree of purity, carrying generally over 90 per cent. carbonate of lime. Its numerous fossils show that it is of marine origin. It is the thickest, purest, most persistent and most massive limestone in the Beaver and Allegheny Valleys. Quite uniformly over a considerable area it is 8 feet thick, but at West Winfield, Butler county, it measures 22 feet. The outcrop of the Vanport limestone in western Pennsylvania is shown on the accompanying maps (Pl. XVII and XVIII).

A view of a Vanport limestone quarry at New Castle, Pennsylvania, is shown in Pl. XIX.

The section in Tygart's quarry at Vanport is particularly thick and shows a color division.

SECTION OF VANPORT LIMESTONE AT VANPORT, PA.

	Feet.
Gay limestone,	7
Shale,	1
Gray limestone,	5
Blue limestone,	5
Total,	18

The division of the limestone into the gray upper portion and blue lower portion is usually well marked throughout the Beaver region.

Over the greater part of Beaver county the Vanport is deeply buried, but it outcrops along Ohio river. It has a thickness of 18 feet at Vanport, its type locality, 16 feet at Industry, 8 feet at Merrill, and 10 feet at Fallston, on Beaver river; elsewhere where observed it is less than 5 feet thick, usually less than 1 foot, and is sometimes entirely absent.

The upper of the two beds is now burned extensively at Vanport for lime, which is of high quality and excellent as a flux for iron, for which purpose it was once shipped extensively to Pittsburg. The lower bed is usually rejected, but there is no reason why this portion should not be suitable for the same purpose. At the time of the construction of the Erie and Pittsburg canal the limestone was used in manufacturing natural cement for the locks.

In Armstrong county it rises above the river at Kittanning and is quarried there by the Kittanning Clay Manufacturing Company, see plate XIX. It is also quarried at Mahoning and West Winfield. In Indiana county it outcrops on Mahoning creek with a thickness of 4 feet. Over three-fourths of Jefferson county the bed has extensive outcrops with a maximum thickness of 4 to 6 feet, but dies out to the southeast and is unknown in Clearfield county. This bed averages about 8 feet in Clarion county, and occasionally runs as high as 15 feet, and is extensively exposed.

The Vanport limestone is the only bed in western Pennsylvania which almost universally contains less than 2 per cent. of magnesium carbonate. The siliceous matter likewise is usually very low, while the proportion of calcium carbonate is high, running between 86 and 96 per cent. The stone is used for ballast, flux, road metal and fertilizer, and also for the manufacture of Portland cement.

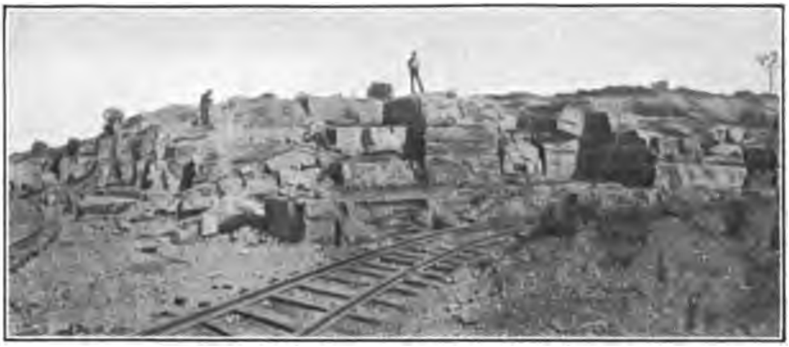

Plate XIX. Vanport limestone quarry at Newcastle, Pa. (Photograph by M. R. Campbell.)

the past; at Goods Mill on Little Mahoning creek; at the Dick farm on Two Lick creek, and possibly at several other localities. Usually, however, the thickness is considerably less than 10 feet.

One of the greatest known thicknesses of the Upper Freeport limestone is at the east end of the west-bound tunnel of the Pennsylvania Railroad at Gallitzin, where the bed, with a few thin shale partings, measures 18 feet 8 inches.

It may be said for the Upper Freeport limestone that, while of very irregular occurrence, it is frequently of workable thickness, and nearly always contains a fairly high percentage of lime, low percentage of magnesia and low percentage of phosphorus, rendering the product suitable for Portland cement, flux or fertilizer.

Ames Limestone. There are several limestones in the Conemaugh formation, but all are thin and of little or no value. The most persistent bed is the Ames limestone (Crinoidal), an impure and very fossiliferous bed averaging 280 feet below the Pittsburg coal. The rock is often entirely composed of crinoid stems and spines and other fossils closely packed together, forming a limestone unlike any other carboniferous bed. This bed, on account of its dark-bluish-gray or greenish-gray color and peculiar fossiliferous appearance, is an excellent reference datum over wide areas. It is, however, of no economic value, being difficult to burn, and is seldom used even for fertilizer. In thickness the bed ranges up to about 6 feet, and is occasionally double.

The Elk Lick is another unimportant bed in the middle of the Lower Barren Measures.

Pittsburg Limestone. One or more beds of limestone of no great importance occur 10 to 20 feet below the Pittsburg coal. They are usually compact and brittle, bluish-gray, and have an irregular fracture. Some analyses show less than 3 per cent. magnesium carbonate. They have been burned extensively by farmers throughout the area in which the Pittsburg coal outcrops for use as fertilizer, and also for building plaster. In some places where handily located, they are crushed for road metal. They are being largely used for this purpose in the vicinity of Pittsburg.

Redstone Limestone. This is a hard, gray, crystalline limestone of some value, occurring below the Redstone coal and 30 to 70 feet above the Pittsburg coal. Its principal occurrence is in the Connellsville basin, where it is rather persistent. On Redstone creek and in the territory between this stream and Allegheny river it is of fair thickness and excellent quality, and throughout Fayette county has been quarried extensively in the past for fluxing purposes to the exclusion of all other limestones. Throughout the greater part of the Monongahela Valley it is usually absent or very impure.

An analysis of the stone from the quarry at Lemont furnace indicates that if the composition given is characteristic of the bed, the percentage of magnesia is too great to allow of its having any value for Portland cement.

Fishpot Limestone. The Sewickley limestone underlies the coal of that name at a distance of about 15 feet and is best known in the Connellsville basin. Toward the south it is thin and of inferior quality, improving northward, but always of irregular occurrence. The greatest thicknesses reported are from 30 to 35 feet, in the vicinity of Greenfield, on Monongahela river; on Redstone creek, in Fayette county, where it is the chief source of lime for agricultural purposes; and at Brownsville. Generally it runs too high in silica for use as a flux. The stone at Oliphant furnace, in Georges township, Fayette county, has nearly 11 per cent. siliceous material, over 80 per cent. calcium carbonate, and 2.2 per cent. magnesium carbonate.

Benwood Limestone. The Benwood is the most important limestone in the Monongahela Valley. It is a double limestone, occurring about 120 feet above the Pittsburg coal. The upper member, or Uniontown limestone, is usually 6 to 15 feet thick, often impure and of a buff color, and is said to be a good natural cement rock.

The lower member is much more persistent than the Uniontown bed. It varies in character from a hard and pure to a very shaly limestone, averaging above 50 feet. The maximum thickness is reached along Monongahela river, where it is sometimes as much as 90 feet. Toward the north it diminishes in thickness, and, where it is exposed along the Pennsylvania Railroad, varies between 7 and 28 feet. The rock is often siliceous or argillaceous and sometimes ferruginous. The bottom is said to be generally the more magnesian, although all portions are extremely high in magnesia, and it is nowhere known to be suitable for Portland cement. In Washington county the stone was considerably used in early days in the manufacture of natural cement. The northernmost outcrop is near Elders Ridge, where it caps several rounded knobs.

Waynesburg Limestone. The Waynesburg limestone, which is a rock of good quality, occurs a few feet below the Waynesburg coal. It is usually from 4 to 20 feet in thickness, and is accessible throughout Fayette, Westmoreland, eastern Greene and southeastern Washington counties. It makes a strong, dark lime.

Upper Washington Limestone. Limestone beds are abundant in the Dunkard formation in southwestern Pennsylvania. The principal one is the Upper Washington, which occurs at a distance varying from 250 to 425 feet above the Waynesburg coal, and is widely distributed in Washington and Greene counties. Its weathered surface is very white in comparison with other rocks in this region, but on fresh fracture the rock is bluish-black or gray. It varies from 4 to 20 feet thick, and has been quarried near Washington, Pa. Locally, it has been burned for fertilizer, and analyses suggest that it might make fair cement.

SANDSTONES OF SOUTHWESTERN PENNSYLVANIA.

By R. W. STONE.

The Coal Measures area of southwestern Pennsylvania as a rule does not contain any high grade building stone, though it is true that some of this stone has been locally used for the construction of churches, school-houses and other buildings. On the other hand there is an abundance of sandstone highly suitable for all the purposes of rough masonry, such as bridge abutments and structural work of that type.

The value of sandstone produced in Pennsylvania for structural purposes for 1906 is as follows, according to the statistics of the Division of Mineral Resources of the U. S. Geological Survey:

VALUE OF SANDSTONE PRODUCED IN PENNSYLVANIA, 1906.

Rough building,	$510,299
Dressed building,	835,841
Road making,	34,000
Railroad ballast,	108,391
Concrete,	103,120
Ganister,	196,804
Riprap,	66,626
Rubble,	152,971
Paving,	112,456
Flagging,	277,623
Curbing,	305,470
Other uses,	21,273
Total,	$2,724,854

This of course includes the whole State. How much of the above amounts come from the area here studied is not given. As a State, Pennsylvania stands first in the production of sandstone. The above table, as will be noticed, does not include sand for the manufacture of glass or other similar purposes, of which Pennsylvania produces a large amount.

The carboniferous rocks west of the Allegheny Front contain 12 beds of sandstone, which, locally, are of some little value. They are mainly gray and buff in color, iron-stained in spots or along joints, and vary from soft and loose in texture to hard and compact. Many of the sandstones are soft when freshly quarried, but harden on the surface on exposure. Although for the most part fairly persistent in occurrence, they all vary greatly in thickness, as has been pointed out in Stratigraphy, and in places are absent or give way to shale. The more conspicuous beds of sandstone above the Mauch Chunk formation are: Connoquenessing and Homewood in the Pottsville formation; Clarion, Kittanning, Freeport and Butler in the Allegheny formation; Mahoning, Buffalo, Saltsburg, Morgantown and Connellsville in the Conemaugh formation; Pittsburg in the Monongahela formation; and Waynesburg in the Dunkard formation.

Pottsville Sandstones. Connoquenessing and Homewood sandstones outcrop along the Allegheny Front, and in the area here mapped they appear abundantly across the center of the Houtzdale quadrangle and in the northeast corner of the Curwensville quadrangle, and in the northern part of the Clarion quadrangle. In the Kittanning and Rural Valley quadrangles they appear along Allegheny river above Kittanning, and on Redbank and Mahoning creeks. They are brought up along Chestnut Ridge and Laurel Ridge. In the New Castle quadrangle they outcrop along Beaver river and Connoquenessing creek. In nearly all of the areas they offer an abundance of stone for rough masonry work. They are coarse grained, gray or white, often highly siliceous, and thick-bedded. In places the massive character gives way to thin-bedded or shaly. The Connoquenessing sandstones average about 40 feet thick each and in places fill most of the interval between the Pocono and the lowest of the Mercer coals. That they often run thin or are replaced by shale is well shown in Pl. VII. The usual thickness of the Homewood, which lies about 50 to 100 feet below the Vanport limestone, also is about 40 feet, often becoming too thin to quarry, and in places reaching 65 feet or more. In Beaver and Lawrence counties the Pottsville sandstones have been extensively quarried on both sides of Beaver river. The Homewood is usually massive, coarse-grained, or conglomeratic, composed of rounded quartz grains cemented with silica and iron, with, locally, white pebbles up to one-fourth inch in diameter. It is of gray to yellow color, measuring from 10 to 60 feet in thickness, with an average of 30 feet. The stratum is characteristically irregular in lithologic character and thickness. It is a cliff-making bed. Along Connoquenessing creek and where exposures appear east of Beaver river between Chewton and New Castle, its horizon is filled with shale. As a rule only about 20 feet are quarried as the upper part of the bed often inclines to be shaly. It is very typically and well exposed in the large quarry at Homewood.

The Upper Connoquenessing sandstone in this district affords dimension stone of good size and quality and when crushed also

A. General view of the quarry of the Conemaugh Stone Company northwest of Curwensville.

B. Corner in quarry of Roaring Run Stone Company, showing face, stripping, etc. North of Curwensville.

Plate XX. Views illustrating the sandstone quarrying industry in Pennsylvania.

makes engine sand and possibly glass sand. It measures up to 60 feet in quarry faces and is a hard, massive, thick-bedded stone composed of angular quartz grains of medium size cemented together with silica. Locally it is irregularly bedded or cross bedded and contains fragments of fossilized tree-trunks. The rock is notably free from iron and is usually white or gray in color, though in places tinged with yellow.

The Pottsville sandstones are extensively quarried in the northeastern part of the Curwensville quadrangle to the north of Curwensville. In that region the Homewood is a massive cliff-making sandstone, often or usually being without bedding planes for a thickness of 40 feet or more. The stone when fresh is creamy or gray in color, except as it is colored by iron. The stone shows along the west bank of Susquehanna river for some miles above Curwensville. It is in better condition for quarrying on Anderson creek and to the north, where it forms a protecting cap over all of the hills, and over much of the country makes a bold outcropping cliff along the hilltops. At one place northwest of Curwensville it produces a notable "rock city." The Homewood is 60 feet thick near Madera in southeastern Clearfield county, where brought up by the McCartney anticline, and is quarried to a small extent. The Homewood is also quarried and crushed for glass sand at Derry, Pa.

Allegheny Sandstones. The rocks of the Allegheny formation occur in abundance throughout western Pennsylvania, except in the southwestern counties. Sandstones in this formation which in place are massive elsewhere are thin and irregular bedded or shaly. Irregular bedding renders them unsatisfactory for working. Although dimension stone of good quality is not common, stone for rough masonry is abundant.

The Clarion sandstone has a thickness ranging up to 40 feet and is found 20 or more feet below the Vanport limestone. It is quarried above Lloydell, where it is favorably located for working and shipping. Great quantities are in sight in this locality. The Clarion sandstone becomes massive, coarse grained and conglomeratic over quite an area in western Clearfield county around Mahaffey and McGees. It is quarried at McGees and Chest Falls for dimension stone. It is also ground for sand for cement making. In most of the quarries only about 20 feet of the rock are taken, though in the railroad cut at McGees the sandstone shows a thickness of 65 feet. This sandstone is also quarried a little on Thompson run in Beaver county. In general the Clarion sandstone is not as thick-bedded and massive as the Homewood.

The Kittanning sandstone occurs locally between the Vanport limestone and Lower Kittanning coal. It is especially prominent as a ledge 20 feet thick along the west side of the Allegheny from opposite Ewing to above Mosgrove.

The Freeport sandstone lies between the Upper Kittanning and Lower Freeport coals. It is a persistent stratum, but varies from massive, and in places conglomeratic, to flaggy and fine-grained. The thickness ranges up to 50 feet. It has been quarried at Industry, on Ohio river, for railroad construction. As given in the section under Stratigraphy, the Freeport reaches a thickness of 70 feet of coarse-grained sandstone in the Allegheny river. Usually, however, it is not well situated for quarrying.

The Butler sandstone, for the most part coarse and heavy-bedded, is in places flaggy and unsuited for dimension stone. Its position is between the Upper and Lower Freeport coals. Near Beaver, where this sandstone is a compact, coarse, fair building material, it was quarried at a number of points many years ago.

Conemaugh Sandstones. The lowest members of the Conemaugh formation are the Mahoning sandstones, which rest on the Upper Freeport coal. They vary from medium-grained, flaggy, or even shaly, to coarse and thick-bedded sandstones, and run from 10 to 40 feet thick. In places they carry small quartz pebbles and are slightly conglomeratic. This stone is quarried by the Kiskiminetas Quarries Company north of Tennelton. The output is large-sized blocks for rough work, adapted for piers, abutments and retaining walls. On the west side of the river opposite Ford City the Mahoning is quarried and reduced to sand for grinding plate glass at Ford City.

In Beaver county the Lower Mahoning sandstone has been extensively quarried at the head of Thompson run, east and southeast of New Galilee, one mile and one-half mile northwest of Cannelton. The Upper Mahoning has been quarried on a small scale near Glen Campbell, in Indiana county. The Lower Mahoning is quarried near Janesville in Clearfield county.

The Buffalo and Saltsburg sandstones are the next vassive members above the Mahoning and are almost its counterpart. They are conspicuous in the vicinity of Saltsburg, making precipitous high ledges along the Kiskiminetas river as a single massive sandstone. This stone is quarried extensively on the hills southwest of West Winfield.

The position of the Morgantown sandstone is about 200 feet below the Pittsburg coal. Although in places it is a clean, gray, massive rock, from which a fair quality of small dimension stone could be obtained, these characteristics are not persistent, and the change in other localities to thin-bedded or shaly rock makes it useless.

The Connellsville sandstone, when present, is found about 40 feet below the Pittsburg coal. It is a coarse sandstone, named from the

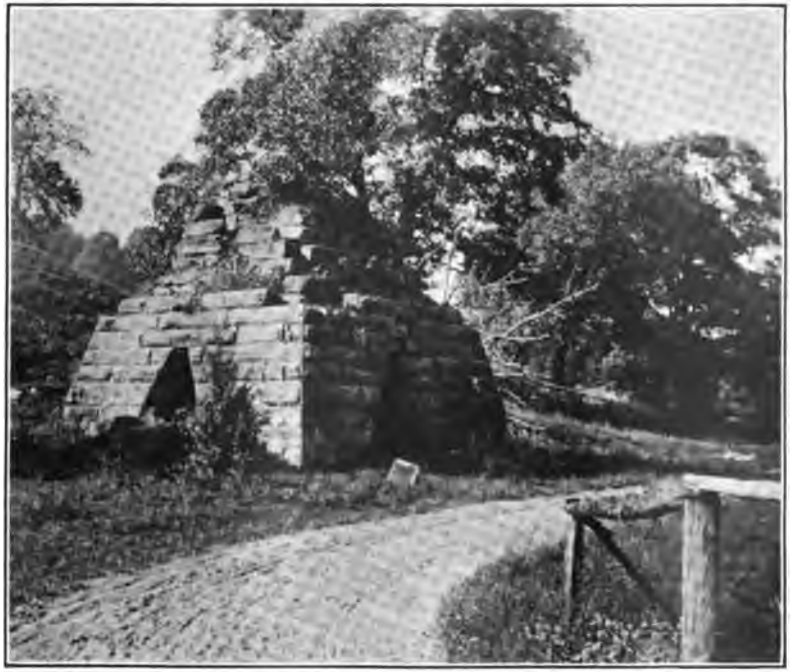

Plate XXI. View of Canoe Furnace, a relic of the iron industry in Pennsylvania in its early days.

city where it outcrops conspicuously. It is usually 30 feet thick, and in its massive condition is a grayish, quartzose sandstone, sometimes iron-stained, and in no way different from other sandstones in the formation.

Monongahela Sandstones. Directly above the Pittsburg coal is the Pittsburg sandstone, a stratum which is variable both in thickness and character, like all the members of the carboniferous formation. Its character generally is massive, but in places it is current-bedded and suited for flagging. Elsewhere it is found to be soft and shaly and would not be recognized but for its position.

In the remainder of the Monongahela formation thin sandstones are abundant, and locally may be sufficiently massive to yield rough building material.

Dunkard Sandstones. The Waynesburg sandstone, at the base of the Dunkard formation and overlying the Waynesburg coal, is confined in its distribution almost exclusively to Washington, Greene, Fayette and Westmoreland counties. It varies from 10 to 40 feet in thickness and in its best development is coarse and massive and inclined to be friable when weathered. In places it contains a few small pebbles, and in the Latrobe syncline is very coarse, while in the Uniontown syncline it is composed of finer material, being shaly, and in some sections absent.

Above the Waynesburg there are no sandstones of thickness or character to attract attention, except that occurring about 130 feet above the Upper Washington limestone. This is quarried near the railroad tunnel east of Washington for curbing and bridge construction.

IRON ORE.

Although Pennsylvania far outstrips all of the states in the production of pig iron, producing almost as much as all of the rest put together, her own production of iron ore is inconspicuous and practically none of it comes from the area here studied. As early as 1792 a furnace for the reduction of iron ore was built near Fair Chance, and from that the State's present great industry has grown. For a long time the many furnaces scattered all over the Coal Measure area drew their ores from the surrounding region, but the advent of the rich Lake Superior ores effectually closed the iron mines of western Pennsylvania, until at the present time their existence is almost forgotten. As the iron ores of western Pennsylvania will have no value as long as the supply of Lake Superior ore holds out, they do not need to be dealt with at any length in a preliminary report of this kind. As a matter of historic interest a picture of one of the old time furnaces in Clarion county is presented (Pl.

XXI), as well as a few notes on the horizons from which the ores were obtained.

The highest stratigraphic position from which iron has been obtained in Pennsylvania is the shale under the Waynesburg coal. These shales sometimes contain considerable quantities of iron nodules. They were once mined in Morgan township in Greene county. The clay under the Pittsburg coal, in Fayette county, has been another source of iron. A typical section as given by Stevenson shows several layers of iron ore running from 0 or a few inches up to a foot or 18 inches, and in one case to 6 feet in thickness. These ores are confined principally to the Blairsville basin though they extend into the edge of Monongahela county, West Virginia, on the south, and into the edge of Greene county on the west.

The principal ore of western Pennsylvania lies directly on top of the ferriferous limestone. It has often been called the buhrstone ore, from the occurrence beneath it sometimes of cherty material. It generally lies directly on top of the limestone, the contact being an irregular one, and it runs from a few inches to a foot in thickness, though sometimes running up to several feet. In such cases it is usually found that the limestone is entirely gone. It is absent over large areas. The ore is evidently a concentrate due to the action of surface or ground waters, and therefore is found in minable condition only near the surface within reach of those waters. It was mined by stripping around the face of the hill. The benches formed by these old strippings stand out to-day as prominent horizontal lines around the landscape in the regions of former mining. As the old pits are only partly filled up, except as they have filled with water, the level of this horizon may often be traced on the new topographic maps by the benches and lines of pits.

The uppermost shale beds of the Mauch Chunk formation in the lower carboniferous are also iron-bearing in Fayette county, and were extensively mined in the early days.

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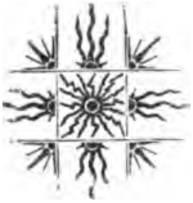

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